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No. 468 ALBANY, N. Y. APRIL 1, 1910

New York State Museum

JOHN M. CLARKE, Director

Museum Bulletin 138

GEOLOGY OF THE ELIZABETHTOWN AND PORT HENRY QUADRANGLES

BY

JAMES F. KEMP Sc. D.

AND

RUDOLF RUEDEMANN Ph. D.

ALBANY

UNIVERSITY OF THE STATE OF NEW YORK

1910

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New York State Education Department

Science Division, December 9, 1909

Hon. Andrew S. Draper LL.D.

Commissioner of Education

SIR: I have the honor to communicate herewith for your examination, the manuscripts and accompanying plates of a treatise on the *Geology of the Elizabethtown and Port Henry Quadrangles* and to recommend, if it meets your approval, the publication of these manuscripts as a bulletin of the State Museum.

Very respectfully

JOHN M. CLARKE

Director

State of New York
Education Department
COMMISSIONER'S ROOM

Approved for publication this 10th day of December 1909

A. S. Draper

Commissioner of Education

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GEOLOGY OF THE ELIZABETHTOWN AND PORT HENRY QUADRANGLES

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John M. Clarke, State Geologist

SIR: In the preparation of the present bulletin the work on the crystalline rocks has been done by the senior author and that upon the Paleozoic strata by the junior author. Geological field work in this area was begun by the senior author under the auspices of the State Museum and as a result thereof a report was rendered on *Geology of Moriah and Westport Townships, Essex county* published in 1895 as Bulletin 14. In this work W. D. Matthew was assistant. In 1894 and 1895 field work was continued in other towns of Essex county under the direction of the State Geologist, with W. D. Matthew and Heinrich Ries as assistants. These results were published in the annual report of the State Geologist for 1893, pages 433–72 and for 1895, pages 575–614. In 1896 the United States Geological Survey authorized the senior author to prepare a folio to embrace the four quadrangles Elizabethtown, Ausable, Mount Marcy and Lake Placid, all to be reduced to one map on the scale of 1:125,000. In the execution of this work the Elizabethtown quadrangle was covered during 1896 and 1897 with the aid of D. H. Newland, J. D. Irving and Charles Fulton. As a consequence of the arrangement perfected by the New York State Geologist and the Director of the United States Geological Survey these results have been transmitted to the former publication. Since the dates referred to, however, the work has been re-

vised, the iron mines carefully restudied and the area of the Port Henry quadrangle has been added, the junior author taking charge of the Paleozoic areas.

The results are herewith submitted, with the maps on the full topographic scale of one mile to one inch. Acknowledgments are cordially made to the Director of the United States Geological Survey and to the younger men who in past years have efficiently assisted in the field work.

Respectfully

JAMES F. KEMP
RUDOLF RUEDEMANN

Plate 1

Ruins of the old French Fort St Frederick, Crown Point. Taken in 1893

GEOLOGY OF THE ELIZABETHTOWN AND PORT HENRY QUADRANGLES

Chapter 1

INTRODUCTION

In colonial times and until a period well into the past century, the natural waterways of North America were almost the sole means of communication. First in importance among them was the great depression occupied by Lake Champlain, Lake George and the valley of the Hudson. It furnished a comparatively easy route between the St Lawrence and the Atlantic. It lay, moreover, in the debated territory between two rival colonial powers, France on the north, and England on the south. The Champlain valley was a fertile district of a character to be easily subdued by the husbandman and its situation made inevitable the result that it should be a scene of conflict and that hostile forces should sweep back and forth along its course. From the first expedition of Champlain in 1609 through the subsequent ones of Abercrombie 1758, and of Burgoyne in 1777 with the returning wave of the Continental army which followed the latter, to the naval battle in 1814, this character was asserted. Throughout all the long stretch of time thus outlined, the great stragetic position on Lake Champlain was Crown Point, within the area discussed in the present bulletin, so that the region presents not only subjects of much scientific interest but it is additionally attractive because it was the scene of the critical events in colonial history. It is the purpose of this bulletin to describe and discuss the local geology and kindred subjects; yet no one can study this region without having constantly in the background of his mind these vital facts of its early settlement and ultimate control. To the strictly scientific portion they furnish a natural introduction.

In May 1609 Samuel de Champlain entered and traversed the lake which now most appropriately bears his name. Its existence and character thus first became known to white men, and in the decades that followed, this knowledge spread among the Dutch and English settlers at the south. By 1690 the commanding situation of Crown Point was recognized in Albany and the name Crown Point was by this time current there. In 1731 the French first took definite possession of Chimney Point on the Vermont side and immediately thereafter of Crown Point itself. A palisade or stockade

was erected which was the style of fortification until 1747 but by 1750 a stone and earthwork fort mounting 20 cannon had been established and named Fort St Frederick. It was visited in the summer of 1749 by Peter Kalm, the famous Swedish traveler and naturalist, who has left for us in his quaint and fascinating book of *Travels in North America* some interesting notes on the local geology. Kalm walked about the ledges and shores both of the mainland and of the point. He noticed the same garnet sand on the beaches which we see today, and was much impressed by the specimens of Cornus ammonis or ammonites which he saw in the limestones, mistaking thus the Maclurites magnus of the Ordovicic for the index fossils of the Jurassic and Cretaceous.[1]

The French were not unmindful of the strategic importance of the headland where now old Fort Ticonderoga is being rebuilt from its ruins, and in 1755 established at this point their Fort Carillon which commanded the portage from Lake Champlain to Lake St Sacrament. Both Fort Carillon and Fort St Frederick were sources of much irritation to the colonists on the south, and finally in 1759 were captured by the British and Colonial forces under Gen. Jeffrey Amherst afterward made baron in 1776. The British then erected on Crown Point the very important fortification which still remains in a fairly good state of preservation with the exception of the old stone barracks within the earthwork. These latter are mostly in ruins. A plan of them is here given based upon a survey kindly made at the writer's request in 1908 by Mr Samuel Shapira of Witherbee, Sherman & Co., and by permission of the officers of the company. The photographs of the earthworks and barracks given on plates 2 to 5 were taken in 1897. The old for remains as a most interesting exhibition of early work of this kind. Its pentagonal outline with the salients and embrasures can be easily followed. It was obviously an undertaking of no small magnitude for its time, and is said to have cost 2,000,000 pounds. Its remains should be carefully guarded and preserved as a State or National reservation.

The old French fort, St Frederick, is much less easy to trace. The lines of its earthworks are, however, not yet fully effaced, and the reproduced photograph on plate 1 will give some idea of their distinctness. The French fort stood at the water's edge, and extended back in a salient quadrangle some 200 feet so that the

[1] Kalm, Peter. Travels in America. English translation in volume 13, page 374 of Pinkerton's Voyages and Travels. Fort St Frederick is described on p. 604–15.

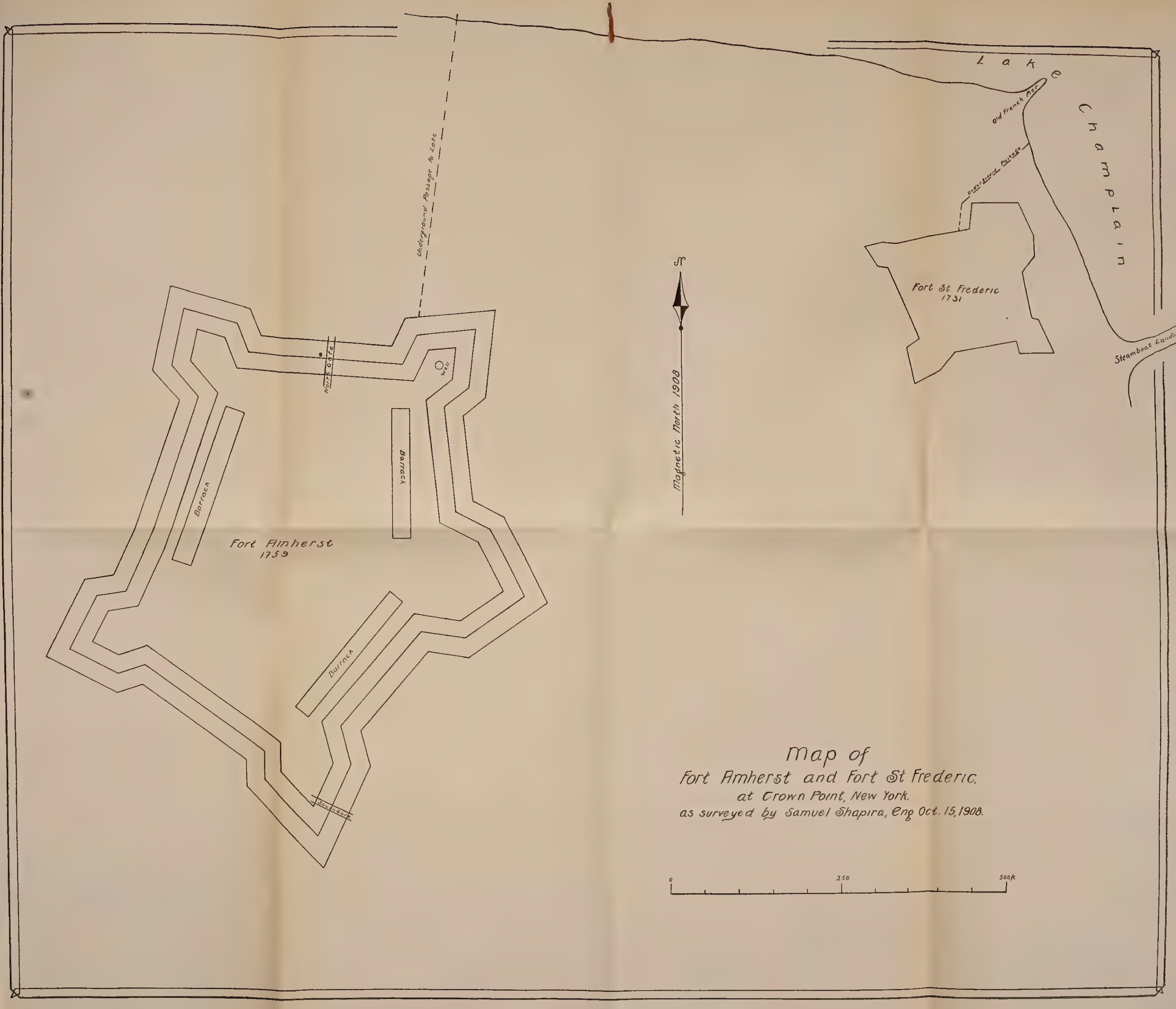

Fig. 1 Map of Fort Amherst and of Fort St Frederic at Crown Point

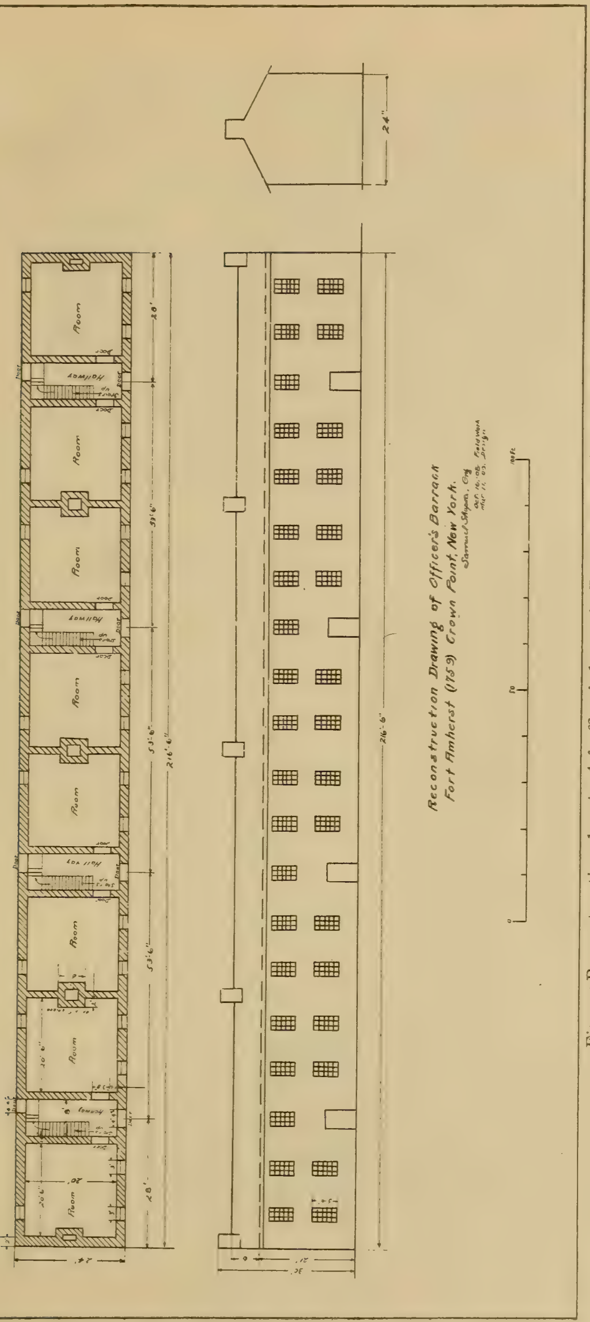

Fig. 2. Reconstruction drawing of officer's barrack, Fort Amherst (1759), Crown Point

British works which are back on the higher ground, cover some part of the site of the former. The accompanying plan of Fort St Frederick is taken from the *New Military Dictionary* 1760.

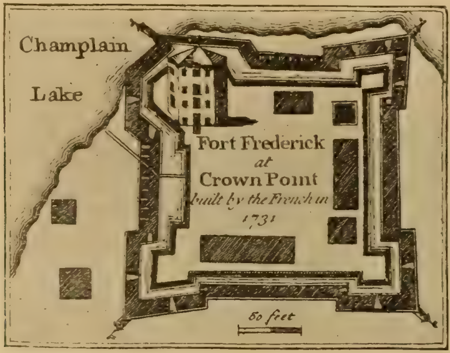

Fig. 3 Fort Frederick at Crown Point

Aside from the settlements immediately around the forts above mentioned and incident to them, peaceful occupation began in the latter half of the 18th century. It was well under way in the opening years of the 19th. Lumbering, farming and above all iron mining and manufacture all developed and became the chief occupations of the inhabitants. Lumbering has practically passed away for the time being, but the other two forms of industry, and especially those of mining and smelting are of exceptional importance.[1]

The area described in the present bulletin is contained in the Port Henry and Elizabethtown quadrangles as topographically mapped by the United States Geological Survey, in conjunction with the State authorities. The Port Henry quadrangle, lying between west longitude 73° 15′ and 73° 25′, is largely in Vermont. Only the strip included in New York is here treated. The Elizabethtown quadrangle extends 15′ of longitude westward. Both quadrangles are embraced between north latitudes 44° and 44° 15′. In these latitudes a quadrangle is approximately 12.75 miles east and west by 17.5 miles north and south. In the Elizabethtown sheet there is therefore included about 225 square miles, and the New

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[1] For the general history of this region, the following are of interest: History of Essex County by Winslow Cossoul Watson, first published in the Transactions of the New York State Agricultural Society, 1852, and separately in Albany, 1869; Pictorial Fieldbook of the Revolution by Benson J. Lossing, 1860. Pages 150–51 relate to the old fort on Crown Point. One of the barracks was inhabited until just before this date. From Lossing's description they have not greatly changed in nearly 50 years.

View of the English fort taken from the eastern parapet, looking northwest across Bulwagga bay. The high peak on the right in the background is Bald Knob; the larger, remote one in the left background is Giant mountain.

Plate 3

View of the parapet of the English fort looking south through the embrasure to the southern and best preserved barracks

Plate 4

View of the English fort looking east from the west parapet

Plate 5

View of the best preserved of the barracks, from the north

York portion of the Port Henry is approximately 68, making a total of 293 square miles. Both sheets lie in the fourth tier from the International boundary and the southern limit is approximately 115 miles from Albany. The area lies entirely in Essex county. The lagest town is Port Henry which is the business center. At the last census it was credited with 1751 inhabitants. The number fluctuates with the activity of the local blast furnace. Mineville, including Witherbee, 5 miles to the northwest, is second. Its population is about the same but it also varies with the operations of the great iron mines. The town of Moriah, which contains them both and other smaller villages, had 4447. Westport town was credited with 1727 people and Elizabethtown village with 491. Both are essentially dependent upon the local agriculture and the summer visitors, with whom both are justly popular. Wadhams Mills has an important water power and electric installation, but the other local aggregations of people, Moriah Center, Moriah Corners, and New Russia are smaller. Back from the lake the rest of the area, except for an occasional farm along the highways is largely a forested series of hills and mountains, broken by precipitous escarpments, extremely rough in their relief. Only two highways cross the 17.5 miles of the western border and of these the northern one is alone much traveled. The southern one, from Underwood to the Keene valley by Chapel pond is none the less one of the finest drives in the mountains.

Along the lake, in the flat forelands, the farms extend continuously and are located upon a level and easily subdued surface. The scenery, embracing as it does this combination of wild mountains and cultivated lands, is of great charm and beauty. The view from Bald Knob commands the valley of Lake Champlain as far as the eye can reach, the distant range of the Green mountains, and the high peaks of the Adirondacks, 30 miles to the westward. It is thus one of the most comprehensive in the mountains and in its physiographic features one of the most suggestive and instructive in the East. No observer, unless dull and unimpressionable beyond belief, can leave it without fairly wrenching himself from its contemplation by force of will, exercised because of the unavoidable pressure of other duties.

Chapter 2

PHYSIOGRAPHY

The lowest point within the area is the surface of Lake Champlain. This varies through several feet between conditions of high and low water but it ranges so near 100 feet above tide, that this

number, so easy to remember, may be established in mind as a datum.

The charts of the survey show by the soundings depths for the lake ranging down to about 400 feet, as a maximum. The deepest portion is opposite Essex and just north of the present map. The deepest point upon the map itself is 334 at the northern end and near the New York shore. A pronounced channel follows along the western side of the lake of varying depths above the maximum to 257 as a minimum before Westport is reached. Off Westport 201 feet have been found. Off Barbers point the depth is 191; off Coles bay 166; a mile and a half south 100; then from 50–60. The deepest near Port Henry is 53. In the Chimney Point passage it is 55, and then farther south less than 30. Undoubtedly the deposits of drift and of Champlain clays mask the natural outline of the bottom. The rocky bed ought to slope downward all the way to the St Lawrence river, although it may be somewhat modified by postglacial warping.

The highest point within the area is Giant mountain at 4622 feet.[1] Thus from the bottom of the lake to the loftiest mountain there is a range of just about 5000 feet. Giant stands a little north of the middle of the western border, and is the eighth in altitude of the loftier Adirondack summits. It forms the culminating point of a group or massif, and has a steep eastern front at the head of an amphitheater. Rocky Peak ridge, one of its buttresses, reaches 4375 but is hardly to be considered a separate mountain. Giant is chiefly ascended from the Keene valley. The trail from Elizabethtown has in later years become obscured. The Keene trail involves a long walk through the woods, until quite suddenly the summit is reached. North of Giant and fairly distinct from it is Green mountain a great east and west ridge attaining 3928 feet and having for its spurs, Tripod, Knob Lock and Cobble.

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[1] By way of comparison a summary of the most elevated peaks may be of interest. They are in order.

	Feet		Feet
1 Marcy	5 344	9 Nippletop	4 620
2 McIntyre	5 112	10 Redfield	4 606
3 Skylight	4 920	11 Saddleback	4 530
4 Haystack	4 918	12 McComb	4 425
5 Whiteface	4 872	13 Sawteeth	4 138
6 Dix	4 842	14 Cascade	4 092
7 Gothics	4 738	15 Porter	4 070
8 Giant	4 622	16 Dial	4 023

No others reach 4000 feet. These altitudes are taken from the topographic maps.

In the northwestern corner is Hurricane mountain, at 3687 feet, the most prominent peak in this section, and one frequently ascended from both the east and the west. In the southwestern corner there is another group of relatively lofty summits, eastern outliers of the Dix massif. Spotted mountain at 3480 is the culmination. They are seldom climbed.

In the central portion of the area the summits are less exalted and yet a number stand out in prominent relief. Raven hill at 1967 near Elizabethtown is more pronounced than its mere altitude would indicate. The open country lying east of it adds to its effectiveness. Broughton ledge with its precipitous southern side, which is not properly shown by the contours, is another marked topographic feature. Harris hill, 2190, is a very characteristic anorthosite dome, and Blueberry hill at 2323, a sharp inverted wedge, is the most decided landmark in this section. For the broad expanse of view and the varied scenery, Bald knob, at 2055, is unrivaled, and is the striking summit which catches the eye of the traveler on Lake Champlain. The attractive and instructive panorama, commanded by its summit, has already been mentioned.

If we seek uniformity or marked relationship in the shape and arrangement of the elevations, we find their distribution not so simple. Yet some striking features can be identified to which more extended treatment may be given subsequently. Thus from Giant to the south and southeast almost all the structural lines are northeast and northwest. The same feature can be followed across the northeastern corner of the Elizabethtown quadrangle, and is pronounced in the Split Rock range. It is also recognizable but more faintly in the Hurricane massif and its outliers.

By contrast, the valley of the Branch which gives the pass for the highway from Elizabethtown to the Keene valley is almost due east and west, and the very marked valley of the Boquet from New Russia to Elizabethtown is almost north and south. Green mountain is roughly east and west, as are Broughton ledge and the unnamed ridge next north. The Bald knob ridge trends north and south and is abruptly cut off toward the lake by the great escarpment, undoubtedly a fault line, which runs from Bulwagga mountain on the south as far as the latitude of Westport. There are thus these less emphatic and easily recognizable features which may be relics of older conditions.

The lowest point along the shores of Lake Champlain is naturally its surface at 100 feet, but the shore line enables one to see at a glance the character of this portion of eastern New York. Ridges

run down to the lake from the southwest forming mountainous escarpments around whose sides the Paleozoic rocks set back in embayments and between which they constitute flat forelands, obviously the western remnants of the level expanses of the Vermont shore. Within the area here mapped there are the Port Henry and Westport embayments, and in addition the northerly prong of Crown Point. Farther south the same relationship reappears in Ticonderoga, and farther north it is very emphatic in Essex and Willsboro. The village of Port Henry is built on a small flat at 240 contour, while the large level stretch southwest of Westport ranges up to the 300 as a maximum. Beyond question these flats are fault blocks.

Escarpments. The relief of the mountains and valleys can hardly be dismissed without mention of the escarpments. They are at times very pronounced. In fact the favorite outline of the eastern Adirondacks is the sawtooth. As the observer follows the sky line from any point of outlook commanding a wide sweep, he can not but be impressed with the moderate upward slope of one side of a mountain, terminating in a sharp, precipitous cut-off on the other. Usually the moderate slope follows the dip of the foliation while the precipitous side is due to a fault. Upon the topographic maps the abrupt character of the escarpment is much softened by the spreading of the contours either on the part of the draftsman or the engraver. Thus the Broughton ledge [pl. 6], 4 miles west of Moriah Center is a sheer cliff two or three hundred feet, almost smooth and scarcely 5 degrees from the vertical. Others of impressive steepness front the road from Underwood past Chapel pond on the northeast side, and many smaller cliffs are on the northwest side of the road which follows the Boquet river to its source south from Elizabethtown. In several instances trap dikes have come up through the cleft which has caused the cliff and portions may remain adhering to the sides of a precipice. One such may be observed along the northwest side of New pond, and another in the cliffs just north of the brook, which reaches Pleasant valley from the north side of Iron mountain. The dikes are shown on the geologic map.

These cliffs are constantly met in traversing the mountains and are often encountered in passing through the woods on the steeper slopes. They make constant detours a necessity. When, moreover, one reaches the summit of a ridge and proceeds along its crest, the way is interrupted constantly by cross-gulches with precipitous sides, through which either a human or a game trail almost always

Plate 6

Broughton ledge, western Moriah; a fault scarp

passes, and in whose bottoms, small isolated swampy places with specially interesting flora may be found. If the northeast ridges from 4 to 7 miles west of Mineville, as shown on the map, are selected and the contours critically observed these features come out strongly. The little isolated dells amid the higher mountains present extremely picturesque spots with often the track of a deer or even the footprint of a bear in the mud.

"The Gulf." At the extreme southern edge of the Port Henry quadrangle and in Bulwagga mountain, there is a deep gorge of extraordinarily short length for its depth. It is one of the most remarkable physiographic features of the entire area. Although on the map a little forking brook is shown coming down from it into the Ticonderoga quadrangle to the south, the amount of water is very small and altogether insufficient to have produced the depression.

Bulwagga mountain is more of a plateau than a mountain summit. Near the head of the gorge it stands at the 1000 to 1100 contour. Suddenly and far more abruptly than the contours on the map indicate, the surface drops three or four hundred feet precipitously away to the eastward. From the projecting spur of Bulwagga, which bounds it on the north side and which reaches a little higher than the 1200 foot contour it must be 600–800 feet to the bottom of the gorge. The entrance to the gorge is quite flat at about the four or five hundred foot contour. To the east the slope drops off with a moderate gradient to the 1401 foot level of the Paleozoic floor. Attempts to get pictures from the upper edge were not very successful as the drop is too abrupt for a camera to take in a significant view. The whole physiographic form and relations remind one of the barrancas of the Mexican plateau in the State of Vera Cruz, and elsewhere. In the Mexican region the streams have eaten back with surprising rapidity into the plateau and their valleys fall away with great abruptness, but in the case of this gorge, there is no water adequate to the task. We must conclude that a small lobe of ice in the closing, and perhaps also in the opening glacial epoch, ate back into the mountains and developed a cirque, on a small scale. The practically precipitous slopes can thus be explained. The bottom is now somewhat disguised by the blocks which have fallen in, and no rock basin and pool such as should exist in a typical cirque are visible. The master joints run n. 40 w. true, and coincide with the axis of the gorge. Some such line of weakness must have located it

originally. The subsequent sculpturing then developed its present form.

From the outlook tower at Cold Spring park on the south one looks into the gorge, but from the summit on the north side the most impressive view is obtained.

Drainage. The larger features of structure which have just been remarked in the review of the physiography have been the chief factors in locating the lines of drainage. The glacial deposits have in a minor but still recognizable way also exercised an important influence.

The chief streams are two, the Schroon river which drains the southwestern portion and which passes to the Hudson; and the Boquet and Black rivers which drain the western and northern portion, combining as the Boquet, to enter Lake Champlain. Between the Schroon and the Boquet, Mill brook with its mouth at Port Henry and Hoisington brook at Westport are the chief streams. Along the shore, however, a number of additional but smaller ones run from the mountains directly into the lake.

The Boquet river after its junction with the Black and after some meanders across the drift, leaves our map at the 270 contour. The Schroon river is higher and passes to the southward just below the 900. The divide or col between the two stands at 1130 feet. The divide is a rather important one in that it marks the boundary between the St Lawrence and the Hudson drainages. Roughly speaking about one fifth of the area discharges through the Schroon river to the Hudson; the remainder sends its waters to the St Lawrence.

At the headwaters of both the Schroon and the Boquet are some extremely interesting features which also extend into the neighboring quadrangles. The marked northeast and northwest structural lines have caused even the little brooks to follow them. We may start at the source of some little tributary, such as the Moss ponds, southwest of Underwood, and follow the stream around three sides of a rectangle, each turn being a sharply angular one.

This peculiar arrangement of the streams, although observed by the writer at the outset of field work, also independently attracted the notice of Prof. A. H. Brigham during a study of the maps, so that the first mention of it in print is from his pen in an article entitled "Note on Trellised Drainage in the Adirondacks" in the *American Geologist,* 1898, volume 21, page 219.

The trellised drainage is believed by the writer to be due to a pronounced system of block faulting which has broken up the

country into these marked divisions, and which by sheeting the rock along the lines of movement has produced the vulnerable portions, searched out by the moving water. Aside from the evidence of the topography the inference is corroborated by the exposures afforded in these and neighboring quadrangles by the waterfalls of which there are a few. Thus at Split Rock falls in the Boquet river about 7 miles southwest of Elizabethtown, the old crystallines are sheeted and crushed in a most significant manner. Precipitous escarpments display the same characteristics and yield often great talus slopes of angular blocks with parallel sides. The localized and close set grouping of the planes of separation irresistibly suggests to the observer a fault line or zone rather than the simple record of joints which of themselves are not easy to understand except as composite faults of slight individual displacement.

Of the geological date of this fault system it is difficult to form an estimate. The youngest rocks affected are Cambric and Ordovicic. The freshness of the relief would suggest a time possibly in the Tertiary, but undoubtedly the plucking of the Continental ice sheet and of local glaciation freshened up the relief very greatly, by the production of bergschrunds.[1]

In the Paradox Lake quadrangle just south, Dr I. H. Ogilvie[2] has detected flat-topped mountains which strongly suggest remnants of an old peneplain, now broken into blocks by faulting. If this peneplain marks the completion of the Cretaceous cycle of drainage as is not improbable, the faults would be of Tertiary date. The suggestion is however but a surmise and, as is always the case with faults in the ancient crystalline rocks, the evidence is less easy of attainment than in the stratified rocks with their contrasted beds and fossils.

Besides the northeast and southwest systems of drainage just described there is in this quadrangle and still more in neighboring ones evidence of north and south valleys, and of east and west ones which are older. The latter are broader and more open; their

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[1] Bergschrund is the word current in Switzerland for the space or chasm which customarily intervenes between a glacier and the rocky walls of the valley through which it moves. It is a place of specially active removal of rocks because in the warmer seasons the ice melts by day from the sun and the water freezes again at night from the cold. Glaciers thus gradually widen their valleys and render the sides very steep. There seems to be no good English equivalent for bergschrund —therefore it is adopted as above.

[2] Geology of the Paradox Lake Quadrangle. N. Y. State Mus. Bul. 96. 1905. p. 468.

sides have gentle slopes and show evidence of much more protracted wasting away. The best example in the Elizabethtown quadrangle is the valley of the "Branch" which enters the Boquet at the village itself. Although the Branch is the smaller stream, its valley, except perhaps at the headwaters, is more open and larger than that of the Boquet itself. From observations on a wide area the writer has therefore been impressed with the probability that the oldest drainage lines were east and west, and north and south. They often correspond with belts of Precambric limestones which furnish comparatively soft and easily eroded rocks, and the resulting topography has a different aspect and character from the precipitous northeast and northwest valleys. The Elizabethtown quadrangle does not furnish however the best evidence and therefore the subject is not further pursued at this point. The citations below will place the reader in touch with the fuller literature so far as it exists.[1] Nevertheless, in the southern central portions of the quadrangle there are two escarpments which run nearly due east and west. One, the Broughton ledge, a most impressive precipice, illustrated in plate 6, and the other less steep, rise on the north side of Crowfoot pond in a series of steps.

Aside from the small feeders or tributaries which have high gradients and cascades, the larger streams are usually marked for a mountainous region by low gradients and slack water until they drop with relative suddenness to Lake Champlain. For example, in a distance of 7¼ mile from Split Rock falls to a point below Elizabethtown the Boquet river meanders for 7 miles through open meadows. Its descent is chiefly concentrated at New Russia, where there is a drop of 40 or 50 feet within less than half a mile, and partly over ledges. Both at Split Rock falls and at the cascades at New Russia the river presents the relationship not uncommon in the Adirondacks, of a waterfall succeeded by an open and level valley, containing a sandy lake bottom or meadow land which the stream next traverses. The Schroon is also a very sluggish stream with a relatively low gradient. Other smaller streams, such as the outlet of Lincoln pond and Ashcraft brook are decidedly swampy.

These relationships are undoubtedly due to the postglacial ponding back of the waters either by the retreating ice sheet on the north or by moraines which for the time furnished a barrier. In

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[1] Kemp, J. F. Physiography of the Adirondacks. Popular Science Monthly, March 1906, p. 195; Ogilvie, I. H. Geology of the Paradox Lake Quadrangle. N. Y. State Mus. Bul. 96.

Plate 7

Bartlett pond near Mineville, filling a hollow in glacial drift. Drift-covered landscape. Giant mountain on right in background; Mt Dix left center. View from Bald Knob

the valley of the Boquet the lake was created whose abandoned bottom now yields the meadows of Pleasant valley. This lake bottom was described by Heinrich Ries in 1893.[1] The ponding back of the waters was discussed four years later by F. B. Taylor.[2] Down stream and in the northeastern edge of the Elizabethtown sheet, there is a morainal barrier which is now cut through. Its top is on the 500 foot contour while the stream flows at 400 feet. This is not quite high enough for the Elizabethtown bottom at 540–60, but it would account for some of the phenomena in the southwestern portion of the Ausable sheet, where lake bottoms are beautifully developed. The Elizabethtown lake bottom has gone to the extent of arable meadows but the one which lies along the outlet of Lincoln pond and which doubtless marks its former extent, is still in the condition of swamp. It is a not uncommon experience to note other little abandoned lake or pond bottoms, too small to be brought out very strongly by the contours, but furnishing a stretch of meadow land or of a small farm. Within the area of the sheet almost all of the stages from lake or pond to meadow, which have been graphically described by C. H. Smyth, jr.[3] can be identified and the significance of these minor features is so plain as to easily attract and impress even the casual observer during drives for pleasure.

Deltas. In no other form of evidence is the effect of the postglacial ponding so clearly indicated as the deltas, and that too immediately beneath a portion of Elizabethtown itself. The flat or terrace shown on the map at the 600 contour and lying in the southwestern portion of the village is a particularly fine example and is almost a dead level. It has furnished the site for the Windsor and Antlers hotels and for the county buildings. Undoubtedly it was built up by the Branch and its upper portion has probably wasted away but little in the time since its construction. It stands quite 40 feet above the lake bottom of Pleasant valley and the 600 foot contour is not cut by the Boquet until we go 3 miles or more to the south at the New Russia cascade. In August 1893 there was a very sudden and heavy storm in this section of the mountains which produced such floods that bridges were carried off and the banks were undermined throughout this and neighbor-

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[1] Ries, Heinrich. A Pleistocene Lake Bed at Elizabethtown, N. Y. N. Y. Acad. Sci. Trans. 1893. 13:197.

[2] Lake Adirondack. Am. Geol. 1897. 19:392.

[3] Smyth, C. H. jr. Lake Filling in the Adirondack Region. Am. Geol. 1893. 11:85.

ing valleys. The Branch cut away the delta face and gave particularly good exposures of which the writer, fortunately in the field at the time, obtained the photograph shown in plate 8. The cross-bedding and the upper horizontal beds both come out very clearly.

This terrace has been the scene of one of the ill advised placer-mining excitements which spread periodically through the mountains. It was prospected by pits in 1895 for supposed gold and platinum.

At the mouth of Roaring brook, just north of New Russia, there is another fine delta terrace placed on the map at a little below the 600 foot contour, but the difference is not great and its upper level was doubtless due to the same hight of water as the one at Elizabethtown.

Along the Schroon river and just west of Holiday pond there is an extensive gravel terrace with pebbles up to 2 inches, and with its top at the 980 foot contour. There must have been ponding of waters at this locality, higher than the Elizabethtown level of 600 feet and the pebbles are so coarse as rather to argue delta conditions, than a lake bottom. The ponding may have been conditioned by a temporary ice barrier. Still farther south a terrace is again pronounced between 940 and 960, where the highway crosses and leaves the sheet. The difference in altitude between this one and the one to the north is not great and they may have been the result of the one hight of water.

Stream terraces. At several places stream terraces are beautifully shown. In the southeasterly oxbow of the Boquet river, in the northeast corner of the Elizabethtown sheet, extending into the Ausable sheet to the north are four terraces, respectively at 8, 18, 22 and 40 feet above the creek, which is here at the 400-foot contour. An additional indistinct one is half way between the 8 and 18 foot ones. Again along the Schroon as it leaves the southern edge of the sheet, there are four terraces, respectively at 894, 900, 920 and 940 feet. Both of these are due to the meanders and downward cutting.

Sand dunes. In the extreme northeastern corner of the Elizabethtown quadrangle and in the point of land between the Boquet and the Black rivers, there is a very sandy area marked by small drifting dunes and by interesting wind-blown phenomena of this character. Ripple marks appear over a portion of the sandy expanse. The whole aspect irresistibly suggests the seashore.

Plate 8

Postglacial delta cut of the "Branch" near Elizabethtown, freshly exposed at time of flood, August 1893

Chapter 3

GENERAL GEOLOGY

Grenville series

Introduction. Far the greater part of the area consists of the ancient Precambric rocks, a very complex group, which, however, can be deciphered into several recognizable and distinguishable components. Along the shores of Lake Champlain in embayments or projections extending from northeast to southwest up into the valleys between the ranges which come down to the lake, are found the Paleozoic sediments, beginning with the Potsdam sandstone and ending with the Utica slate. One dike of igneous rock has been found, which cuts the Paleozoic strata. Some miles west of the Champlain valley and separated from the main Paleozoic exposures, one outlier of Potsdam has been discovered and there are indications of a second, 1½ miles west of Elizabethtown, although only loose float has been seen. The Precambric rocks are usually metamorphosed and are in instances much changed from their original condition. The Paleozoics are not greatly recrystallized and are much contrasted with the older formations. The two can well be treated separately and, as here, by different writers.

Precambric formations in general. The Precambric complex is separable into an older sedimentary portion and a later igneous portion. The sediments occupy far the lesser area, and must be but a fragment of what was originally a widespread series, which has been invaded, broken up and metamorphosed by the eruptives. In fact one can only gain a comprehensive grasp of the total geology by picturing a sedimentary area penetrated and overwhelmed by a vast igneous outbreak. We have, however, only the deep seated rocks. There is reason for believing that the overlying volcanics which probably accompanied them were all worn away long before the Potsdam epoch opened. With them went also undoubtedly a vast amount of the ancient sediments. The grounds for this belief are, the relatively small amount of the sediments now remaining; the deep seated character of the eruptives; and the need of assuming some load now gone, beneath which these igneous rocks could crystallize in their present coarseness of grain. It is also conceiveable as an alternative that the igneous rocks were altogether intrusive, and that there were enough sediments over them to supply the pressure and the conditions of slow cooling. We can only contrast the two possibilities since no actual trace of one remains more than of the other.

The Precambric rocks are classifiable in order of age from the latest to the oldest as follows:

The unmetamorphosed basaltic dikes

The eruptive complex of more or less metamorphosed granites, anorthosites, syenites, gabbros and intermediate types.

The Grenville series of limestones, ophicalcites, schists, and sedimentary gneisses

Grenville series. The name Grenville was originally given by Logan to a series of rocks in all respects similar to the one here under discussion and developed in the township of Grenville, Ontario. Ebenezer Emmons in his early work in the Adirondack area spoke of them as primary, and, under this head, placed the limestones (called primitive limestone) and the serpentine with the igneous rocks, while the gneiss was classed with the stratified. It is one of the curious instances of the changes in geological thought, that 60 years later these views are exactly transposed. In later years the wise custom has developed of applying geographical names to formations and for this reason the term Grenville is here adopted. It is true that a gap intervenes between the Adirondacks and the Canadian exposures in Quebec and Ontario, and that this gap is covered by the Paleozoics, but the similarity of the old sediments in both areas is so great, that there seems little doubt that they are equivalents. The International committee, which visited both regions in 1906 and submitted a report on the correlation of the two were at least sufficiently impressed with the similarity to recommend the uniform use of Grenville.[1]

The Grenville strata are widespread in the Adirondacks, scarcely a quadrangle being without them. On the Port Henry sheet and along Lake Champlain just north of Port Henry is one of the best exposures in the eastern mountains, but they also appear at a number of other localities in the area here described.

The most prominent and easily recognized of the members is a white crystalline limestone, very coarse grained and seldom pure or uniform over any great width. It is marked by small inclusions of pyroxene, graphite and less common individual minerals and by larger streaks and pegmatitic aggregates of coarse quartz, feldspar, hornblende, biotite, tourmalin, titanite, pyrrhotite and scapolite. Where the limestone has been quarried for fluxing purposes in the iron furnaces, as has been the case near Port Henry, large dumps of the rejected silicates have accumulated, and now afford

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[1] Jour. Geol. 1907. 15:191.

Plate 9

Faulted dike, now hornblende schist, in limestone; near Pilfershire mines

interesting material for the mineralogist. This limestone is a fairly pure calcite.

Overlying the limestone stratum at Port Henry there is another of ophicalcite, or of limestone speckled with included masses of serpentine. This stone has been the object of quarrying and, furnishing as it does, a variety having a white base with light and dark green mottlings distributed through it, has commanded some attention as an ornamental stone under the name of verde antique, or Moriah marble. The serpentine is believed to be due to the hydration and alteration of original diopside, whose unchanged cores may be sometimes detected within the mass of serpentine.[1] This is practically the same rock as that which furnished the Eozoon canadense, to the early observers, but no good specimens of this exploded organism have been discovered.

A very characteristic minor associate of the limestones is a lemon-yellow quartzite or quartz-schist, with more or less disseminated graphite. The yellow color is doubtless due to decomposing pyrites and the rock will often yield the astringent taste of iron sulphate.

Black and coarsely crystalline hornblende schist is also a common associate of the limestone but in relatively small amounts. It may contain large red garnets. The observer is often puzzled whether to interpret this rock as an altered intrusive mass of gabbro or as a metamorphosed sediment. There are probably cases of both. The remarkably regular masses which cut across the exposures, and have a uniform and moderate thickness suggest an intrusive origin most strongly of all. Over the Pease quarry just north of Port Henry there is such a black band, and one courses through another quarry in Pilfershire, southeast of Mineville. Along the Delaware and Hudson railway tracks on the lake shore north of Port Henry where there is an irruptive contact of gabbro and basic syenite and limestone one can see the igneous rock tonguing out into the limestone and apparently pinched off at times by the dynamic disturbances. While it is entirely possible that the hornblendic rocks have been derived from aluminous bands in the original sediment, which might yield greater or less amounts of hornblende, yet we are dealing with a district in which are numerous intrusions of gabbro and basic syenite and where apophyses are abundant. The marked plasticity of the limestone under pressure

[1] Merrill, G. P. Notes on the Serpentinous Rocks from Essex Co., N. Y. etc. U. S. Nat. Mus. Proc. 1890. 12:595–600.

tends greatly to disguise the relationship and to render a demonstration difficult. Igneous phenomena and their expiring effects must have been very general and have probably occasioned widespread recrystallization. Undoubtedly they have set in migration many heated solutions.

The limestone becomes at times extremely small in amount and may be represented by little more than calcareous streaks amid more siliceous rocks, such as mica schist and quartzite bands. The whole may be folded in a most remarkable way. The more resistant silicates having been involved in a plastic medium like calcite have been bent into shapes that seem almost beyond the power of brittle minerals to assume. The presence, however, of the limestone is indicated by the pitted and cavernous weathering.

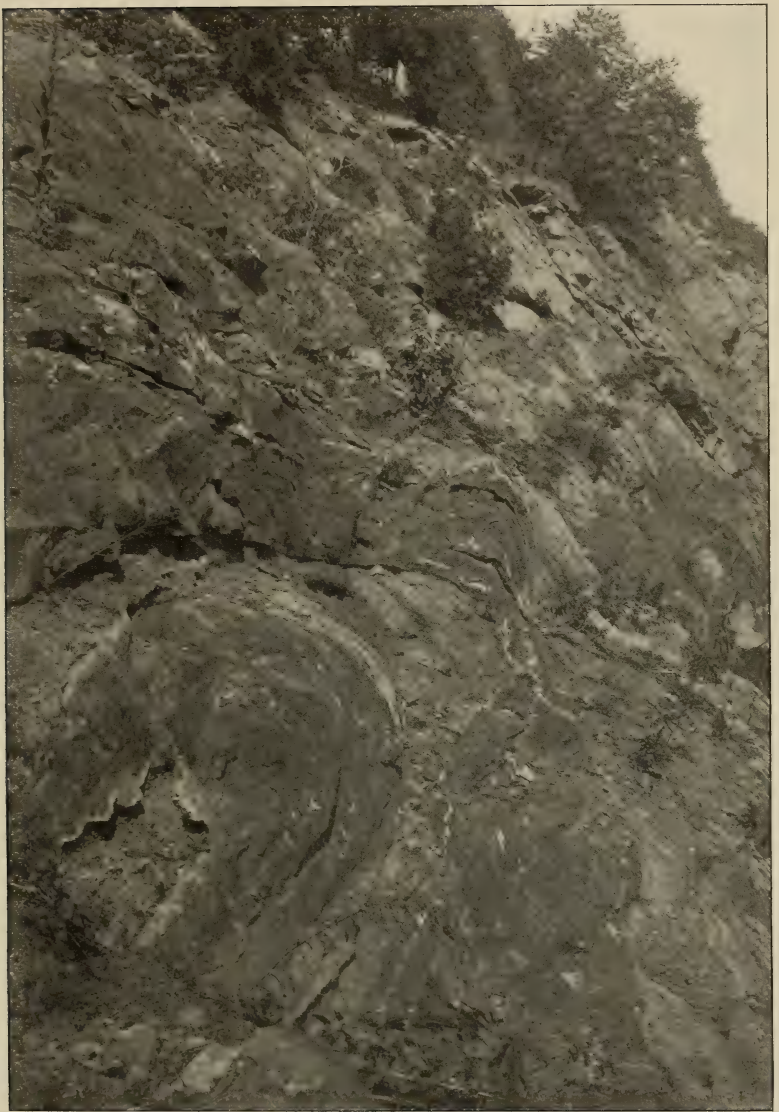
Mica schist or schistose gneisses are known in several localities which also represent the sedimentary series. The rocks are thinly laminated and are much more abundantly provided with biotite than are the eruptive gneisses. The banding runs regularly for greater distances and reproduces the persistent bedding of sediments rather than the sheared and dragged individual minerals of the eruptives.

Besides the more schistose gneisses there are others less thinly or regularly banded and yet not corresponding exactly to any of the well defined eruptive rocks. Where they display sharp contrasts of light and dark bands which are persistent over distances of several feet or more and which are difficult to explain except on the basis of the contrasts in composition which might arise in sedimentation, the writer's disposition has been to group them with the sedimentary types. It is realized that eruptive rocks themselves do display marked banding and gneissoid structures which are due to magmatic differentiation,[1] but yet in open questions like those presented in the Adirondacks, as a matter of opinion the writer leans rather to the sedimentary interpretation especially when the rocks are associated with undoubted sediments.

Some complication arises because of the abundance of pegmatitic matter even on a small scale. Injected gneisses are not unknown and inasmuch as such quartzites as can be recognized in the region are so thoroughly recrystallized as to simulate vein quartz or pegmatitic quartz, lenticular masses of this character may at times give rise to the suspicion of old sandstones. Well defined quartzites are, however, much less in evidence in the two quadrangles under discussion than in several to the south.

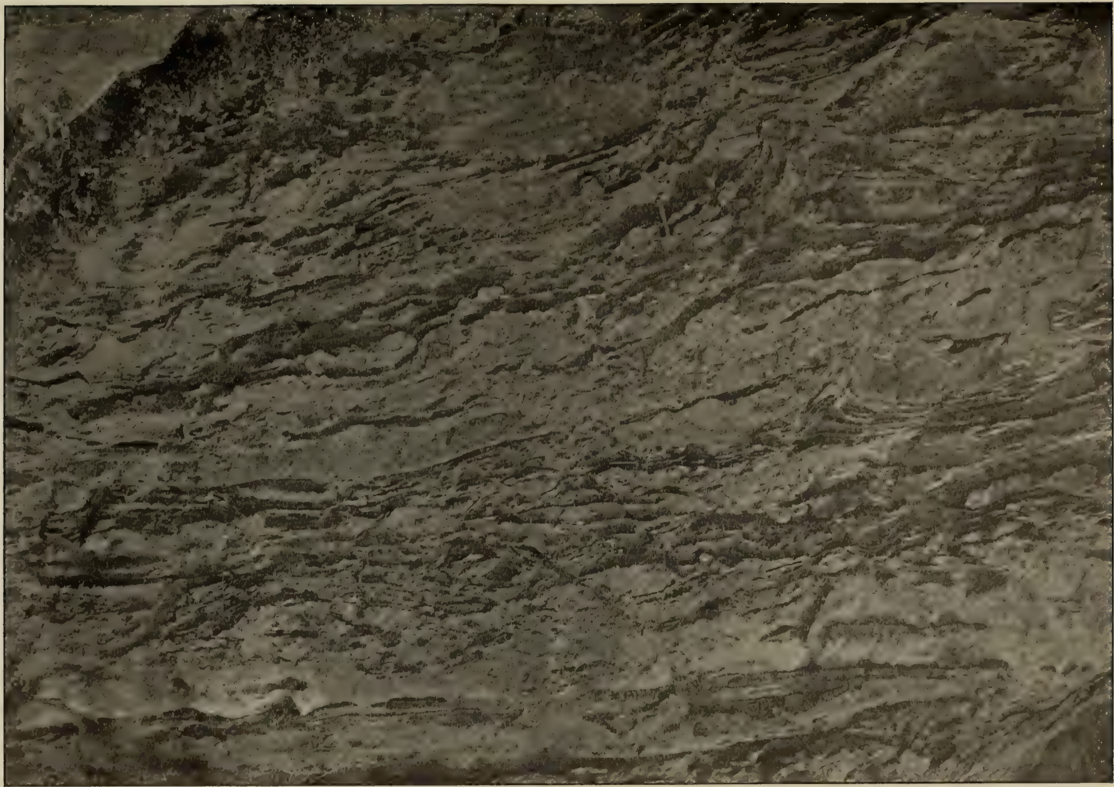
[1] As very clearly shown by Sir Archibald Geikie and J. J. H. Teall for the gabbros of Skye. Geol. Soc. Lond. Quar. Jour. 1894. 50:645.

Plate 10



Folded interbedded schist in Grenville limestone, along the Delaware & Hudson Railroad, north of Port Henry

Plate 11



Grenville limestone along Delaware & Hudson Railroad, north of Port Henry; charged with streaks of silicates and weathered

In the Paradox Lake quadrangle which lies next south of the Elizabethtown and also in the Whitehall, which is southeast of the Paradox Lake, there are extensive developments of a richly garnetiferous, green gneiss, often with much sillimanite. None of this has been observed in the Elizabethtown-Port Henry area. Its original is believed to be a somewhat calcareous shale and it is characteristically associated with the graphitic schists or quartzites which are the commercial sources of graphite. Its absence would argue some change in the character of the Grenville sedimentation to the north, presumably to more purely siliceous or feldspathic materials, whose metamorphic derivatives lack both the lime and the carbonaceous components.

In addition to the above, which may be considered fairly well defined sedimentary types, there are great masses of decidedly gneissoid rocks, usually granitic or at least quartz-bearing in composition, with hornblende and augite as the common dark silicates and with coarse crystallization. They are well shown in the ridge of Bald knob and they are extremely difficult to interpret. The writer's disposition is, on account of mineralogical composition and associations to regard them as igneous in character. They are placed with the syenite series as an acidic extreme. It is realized that another observer might develop a strong argument for their sedimentary characters. It is felt that the best course is to fully and fairly state both cases hereafter.

Chapter 4

GENERAL GEOLOGY (*continued*)

Metamorphosed eruptives

This group is contrasted with the next one of the unmetamorphosed basaltic dikes, because the latter are obviously much later and because they followed the period of metamorphism and crushing, presumably also of extensive erosion, to which the former were unquestionably subjected. At the same time it is believed that the dikes are older than the Potsdam and that they belong to an entirely different set from the ones which penetrate the Paleozoic sediments[1] in adjacent areas.

The older eruptives with the possible exception of some exposures of the basic gabbros constitute extended and huge masses

[1] See in this connection the following paper by H. P. Cushing who was the first to show the distinction between the two groups. On the Existence of Precambrian and Postordovician Trap Dikes in the Adirondacks. N. Y. Acad. Sci. Trans. 1896. 15:248.

of plutonic rocks. They are batholiths or great, deep seated volume, of irregular shape. The included fragments of older rocks which have from time to time been detected demonstrate their intrusive nature. These and the nature of the intrusive contacts give such clues to their relative ages as can be obtained. The original outlines of the intrusions, that is, the evidence as to whether they ever assumed the laccolithic or other definite shapes, have been rendered wellnigh undecipherable by faulting and erosion.

Granites and related types

There are several areas to which this name has been distinctively applied. While they are described before the anorthosites and other eruptives their relations to the latter are obscure. In general they are believed to be older, but there is little ground for this belief other than their intimate association with the Grenville. Their distinction from the acidic members of the syenite series is, moreover, not in all cases clear; and the possibilities of the occurrence of shales and feldspathic sandstones in the Grenville, which might yield, upon extreme metamorphism granitic gneisses, have not been overlooked. Nevertheless both in the field and in the laboratory the occurrences here colored and described as granites, have impressed themselves as sufficiently distinctive to justify the procedure.

The largest area is in the southeastern corner of Bulwagga mountain. A biotite granite is very abundant all through this portion of the sheet, so much so as to be the predominant rock. While it may not be the exclusive member, the variations can not well be shown in colors. Excellent exposures appear near the iron bridge at the headwaters of Grove brook. In their section microcline is the most abundant mineral while quartz and biotite practically complete the slide. This combination is in contrast with the mineralogy of the other groups of eruptives. Both microcline and biotite are seldom seen in the latter, and the inference is natural that when they predominate we are dealing with a separate intrusive.

In the western portion of the area colored green, red granitic rocks have been observed, which reveal under the microscope no dark silicates, but which have only finely striated plagioclase and quartz. A few decomposition products, perhaps from dark silicates, and a few tiny zircons complete the slide.

Throughout this granitic area much pegmatite is present and the granites are often cut by it.

About 3 miles north of Port Henry another area of small dimen-

sions appears on the east and west road. To the observer in the field this appears like a pronounced intrusive granite, sheared more or less into a gneiss, but different from both the syenite series and the Grenville. The microscope reveals quartz, microcline, microperthite and hornblende. It is, therefore, not so sharply contrasted with the acidic members of the syenite series as is the Bulwagga occurrence, in that it has microperthite and hornblende, but it has microcline and in the ledges it looks unlike the syenite series.

There are two other small areas colored for granite, and lying southwest of Westport. Both of these are coarse gneisses, reddish in color, with their quartz and feldspar in little, interleaved lenses, up to an inch in length. No microscopic slides have been prepared and the rock might perhaps be justifiably placed with the syenite series. In the field it was believed to be different.

Besides the occurrences actually colored, there are one or two others deserving mention. In the gorge of Mill brook, just north of Port Henry, and a short distance above its mouth, there is a band of white granitic rock, several hundred feet thick, in the midst of the Grenville limestones. It is obviously much crushed, is dense, white and granitic in aspect. Under the microscope its components are microperthite, microperthitic microcline, quartz, plagioclase, biotite, garnet and zircon. It is difficult to decide whether this is an intrusive granite or an altered sediment, but the former is the more probable.

A mile west, up Mill brook, is the old Lee mine; its walls are a red granitic rock now strongly gneissoid. Much the same rock appears in the walls of the old Essex county ore bed in the northern slope of Bulwagga mountain, but all these last three have been colored in as Grenville. Again in the ridge, an eighth of a mile north of the east end of Crowfoot pond, granitic gneisses again appear, different from the run of the syenite series, but no special color has been given them.

Anorthosites

The anorthosites are believed to be the oldest of the eruptives. They certainly followed the sediments because of the included masses which will be later described. They preceded the Split Rock falls type because we find inclusions of them in the latter. They are believed to be older than the syenites, not from any positive evidence in the area under discussion but because they have been clearly shown to be such by H. P. Cushing in the Long Lake

quadrangle, where the writer has had the privilege of seeing the critical exposures.[1] The syenites are essentially the same kind of rock in both localities and in default of positive evidence which may appear at any time within the present area, this relationship is assumed.

The anorthosites were called by Professor Ebenezer Emmons in his extremely valuable Report on the Second District, "hypersthene" or "labradorite rock," but inasmuch as the hypersthene is very subordinate and as neither of these is a good rock name, the term first employed by Dr T. Sterry Hunt in Canada, is here preferred, as it is generally by geologists today.

The anorthosites vary from almost pure aggregates of plagioclase crystals through variations caused by increasing amounts of a pyroxenic component. The commonest of the pyroxenes are hypersthene and green augite, the latter on the whole being perhaps more abundant than the former. More or less titaniferous magnetite also appears. The rocks are normally very coarsely crystalline. In the central portion of the great masses, feldspar crystals, apparently not connected with pegmatite veins may sometimes be seen as large as a man's hand. Crystals two or three inches across are not uncommon. Well crystallized and uncrushed specimens are rare. The entire area has been subjected to such severe pressure and granulation that the outer borders of the crystals are almost always crushed to a finely granular and whitish mass. Within this rim the bluish nuclei of the plagioclases remain. When shearing and dragging has been added the nuclei yield augen-gneisses of the most typical and instructive kinds. The crushing may go so far as to destroy all nuclei and leave a whitish or greenish pulp of secondary products. This is closely akin to saussurite. When weathering is added the rocks are often extremely white on exposed surfaces, appearing almost as if whitewashed.

The plagioclase crystals sometimes assume elongated forms and suggest a coarse diabasic texture when there is sufficient of the dark silicates to bring this out. Rarely the plagioclase exhibits the characteristic irridescence of certain labradorites. It has not been noted in this quadrangle but in the Mt Marcy group it is not uncommon in the beds of brooks, where either from pebbles, by chance properly cut, or from the smooth bed rock the irridescence flashes out to the observer.

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[1] Cushing, H. P. Geology of the Long Lake Quadrangle. N. Y. State Mus. Bul. 115. 1907. p. 481.

The variety of the plagioclase is best shown by the chemical analysis later cited but it can also be determined in an approximate way by means of the extinction angles. Measurements of specific gravity would also be significant but they have not been used as the above tests were esteemed sufficient. The plagioclase lies most often just beyond the labradorite ranges of Ab_1 An_1 to Ab_1 An_2[1], yet short of the bytownite of Ab_1 An_3.

In the more basic varieties we find the upper limits of the bytownite series also represented.

Under the microscope and when the original texture of the rock has not been crushed and destroyed, the thin sections show between crossed nicols the characteristic twinning of the plagioclases in a remarkable degree of perfection. For purposes of instruction few rocks are so well adapted for illustrating these phenomena. At times the bands cross the crystals with mathematical regularity and perfection; again they interpenetrate and pinch out like interlocked fingers and hands. Even with low powers the plagioclase reveals the very minute dusty inclusions, which in somewhat sparse arrangement are distributed throughout the clear mineral. With high powers the dust is seen to be in largest part an opaque to dark brown mineral, in prismatic or tabular form according to the orientation and doubtless ilmenite. Rarer pale green fragments are probably diopside and spinel. The inclusions may be strung out in lines parallel to the main twinning. They are never abundant enough to affect the transparency of the slide in any appreciable degree and in this respect they are inferior in amount to those in the basic gabbros to be later described.

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[1] In the algebraic designation of the plagioclases, they are considered combinations of the albite molecule, Na_2O, Al_2O_3, $6SiO_2$, written Ab and the anorthite CaO, Al_2O_3, $2SiO_2$, written An. The following varieties are recognized by students of rocks.

Albite	Ab_1 An_0 through Ab_8 An_1
Oligoclase	Ab_6 An_1 through Ab_2 An_1
Andesine	Ab_3 An_2 through Ab_4 An_3
Labradorite	Ab_1 An_1 through Ab_1 An_2
Bytownite	Ab_1 An_3 through Ab_1 An_6
Anorthite	Ab_1 An_8 through Ab_0 An_1

Although the above is the assignment of species generally given in the textbooks it is not a good one, since there are uncovered gaps between each group. Ab_1 An_7 for example is not provided for. It should read Albite Ab_1 An_0 to Ab_8 An_1; Oligoclase Ab_8 An_1 to Ab_2 An_1; Andesine Ab_2 An_1 to Ab_4 An_3; Labradorite Ab_4 An_3 to Ab_1 An_2; Bytownite Ab_1 An_2 to Ab_1 An_6: Anorthite Ab_1 An_6 to Ab_0 An_1.

Many years ago the late George W. Hawes[1] noticed in slides of these rocks some feldspars which failed to afford the twinning striations yet which he suspected of being plagioclase. Analytical tests demonstrated that they were. The same untwinned character may reappear so that the observer must be on his guard, but it is also true that a chance section parallel to the twinning plane would also be without the striations.

The analyses demonstrate the presence of potash quite without exception. The extreme rarity of biotite in the localities where the specimens taken for analysis were collected make it practically certain that the potash is in the orthoclase molecule and that this feldspar is in the rocks up to 5 per cent or over. It would also yield untwinned feldspar, which could only be distinguished from plagioclase by refined optical tests.

The analyses prove that quartz is at times present in amounts even reaching 8 per cent. The observer would need to exercise care not to overlook this mineral, yet despite the rather large percentage indicated by the recasting of the analyses it is rare to detect it in the slides. It is possible that it may be separated in part during the process of saussuritization, and be so finely divided in this indefinite, cloudy mass as to escape notice.

Microscopic study has shown that the commonest and most widely distributed pyroxenic component is a pale green variety, no doubt near diopside if not actually this molecule. The relatively high percentage of lime in the analyses is sufficient to more than satisfy the anorthite molecule and still leave an excess for the pyroxene, while the relatively low magnesia and iron serve to keep the hypersthene molecule somewhat in the background. Hypersthene is, however, abundant and widely distributed and as soon as the percentages of magnesia and ferrous iron rise and the anorthosites develop larger percentages of the pyroxenic components, the hypersthene becomes prominent. In the more coarsely crystalline and pegmatitic phases the hypersthene assumes a coarseness of crystallization which combined with its easily recognized bronze luster, makes it catch the eye of the observer and convince him of its presence. In the typical anorthosites the pyroxenic components are smaller in size than the feldspars and are packed in between the latter. Actual contact between the two, and especially in the

[1] Hawes, George W. On the Determination of Feldspar in thin sections of Rocks. U. S. Nat. Mus. Proc. 1882. 4:134-36.

crushed and sheared varieties is often prevented by the intermediate rims of garnet to which reference will be made later.

Just east of Elizabethtown village in Green hill and Raven hill as well as to the north in the Ausable quadrangle, the anorthosite has much reddish brown biotite instead of the exclusive pyroxenic mineral. The feldspar is also often reddish or brownish and as crushing is not pronounced the rock looks much more like a coarse mica-syenite or nephelite-syenite than like anorthosite. Yet microscopic investigation has invariably shown the feldspar to be plagioclase of the normal type.

The anorthosites are believed to grow more basic toward the borders. The pyroxenic component becomes more and more pronounced and in the end instead of forming 5 to 15 per cent of the rock, it may be 25 or over. In this respect the writer's observations are in accord with those already published by H. P. Cushing for the northwestern areas. The rock then shades into a very coarse gabbro, but the plagioclase is always the most prominent member and in the field in order to maintain the distinction between the anorthosites and the basic gabbros these varieties have been called pyroxenic anorthosites. The sole difference is the increase in the bisilicates.

Another mineral of almost universal occurrence in the anorthosites is garnet. Over much of the area it is rare to find the labradorite in contact with the titaniferous magnetite or pyroxene. Almost always there will be an intermediate rim of garnet which surrounds the pyroxene or iron ore like a little crown of highly refracting pink grains. Even in the hand specimens the rock is a very beautiful one but under the microscope where the garnets stand out in relief the effect is even more impressive. The garnet rims are not limited to the anorthosites but are found in the rocks of the next type and also in the basic gabbros under which they will be again referred to as the garnets are accompanied by other minerals. The rims rarely appear in the syenites.

Larger masses of deep red garnets are also sometimes met, looking like knots in a board. They have probably recrystallized from pyroxenic material once present in the anorthosite.

Chemical composition. No special analyses of the typical anorthosite from this area have been prepared. The rock seems so simple in its mineralogy as scarcely to require them. Such analyses, however, as have been made of similar types either in neighboring or remoter localities, even including Norway, are given below, together with the percentage composition in actual minerals

when the analyses are recast according to the methods now much in vogue and extremely useful.[1]

	1	2	3	4	5
SiO_2	59.55	54.62	54.47	53.43	51.62
Al_2O_3	25.62	26.5	26.45	28.01	24.45
Fe_2O_3	.75	.75	1.3	.75	1.65
FeO	......	.56	.67	......	5.3
MgO	tr.	.74	.69	.63	1.21
CaO	7.73	9.88	10.8	11.24	9.97
Na_2O	5.09	4.5	4.37	4.85	3.49
K_2O	.96	1.23	.92	.96	1.27
H_2O	.45	.91	.53	tr.	.72
P_2O_5	......	......	......	......	.01
MnO	......	......	......	......	.1
	100.15	99.69	100.20	99.87	99.79
Sp. gr.	2.66	2.7	2.72	2.67	2.798

1 Chateau Richer, Quebec. T. S. Hunt. Geol. Sur. Can. 1863.

2 Keene valley. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

3 Summit of Mt Marcy. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

4 Nain. Labrador. A. Wichmann. Zeitschr. d.d. Geol. Gesellsch. 1884. 36:491.

5 Carnes Quarry, Altona, Clinton co. E. W. Morley for H. P. Cushing. N. Y. State Geol. 19th An. Rep't. 1901. p. 58.

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[1] The recasting of analyses was first practised by W. C. Brögger of Christiania about 1890, and has given a new significance to the chemistry and mineralogy of rocks. A simple exposition of the methods employed will be found in Kemp's *Handbook of Rocks,* the calculations being pursued only so far as they give results representing actual rock-making minerals. A more elaborate method has been developed by Messrs Cross, Iddings, Pirsson and Washington in *The Quantitative Classification of the Igneous Rocks,* but in its application the authors are forced because of the complicated mineralogy of many rocks to assume some minerals or molecules which, so far as we know, are not in the rocks under discussion. While the variation from the actual mineralogical composition is oftentimes not necessarily great, yet hypothetical conditions are unavoidably assumed. In the recasting here employed, only those mineralogical molecules are used which we have reason to believe are in the rock. While the results are not mathematically accurate and while in some cases an excess or a deficit of a component has been encountered, yet the results must be very near the truth. They have their value in that they focus attention upon the percentages of the several minerals rather than, as in chemical analyses, upon uncombined oxids.

	1	2	3	4	5
Quartz	8.64	1.56	1.62	2.4	5
Orthoclase	5.56	7.23	5.004	5.56	7.5
Plagioclase	81.322	82.2	84.186	91.57	61.7
Magnetite	.464	.93	1.856	.464	2.4
Kaolin	2.58	3.87	2.58	......	......
Excess Al_2O_3.........	1.122	......	......	......	......
Water	.09	.11	.15	......	......
Garnet	......	......	......	......	11.75
Diopside. Hypersth...	......	4.3	4.616	3.224	11.
Light colored min....	99.234	93.97	93.39	97.14	74.2
Dark colored min....	.464	5.23	6.572	3.688	25.15
Plagioclase	$Ab_1\ An_{1.7}$	$Ab_1\ An_{2.4}$	$Ab_1\ An_3$	$Ab_1\ An_{2.1}$	$Ab_1\ An_{2.4}$

1 Chateau Richer, Quebec. T. S. Hunt. Geol. Sur. Can. 1863.

2 Keene valley. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

3 Summit of Mt Marcy. A. R. Leeds. N. Y. State Mus. 30th An. Rep't. 1878. p. 92.

4 Nain. Labrador. A. Wichmann. Zeitschr. d.d. Geol. Gesellsch. 1884. 36:491.

5 Carnes Quarry, Altona, Clinton co. E. W. Morley for H. P. Cushing. N. Y. State Geol. 19th An. Rep't. 1901. p. 58.

In the quantitative system the first four analyses belong in class I, Persalane, order 5, Perfelic, Canadare. No. 1 is in rang 3, Alkalicalic, subrang 5 Persodic. Nos. 2, 3 and 4 are under rang 4, Docalcic Labradorase, subrang 3, Persodic, Labradorose. No. 5 belongs in class II, Dosalane, order 5, Perfelic Germanare, rang 4, Docalcic, Hessase, subrang 3, Persodic, Hessose.

Of the five analyses the first four are characteristic anorthosites but the last marks a transition to the gabbros proper. The larger percentages of ferrous iron and magnesia are the indication of this and are of course the result of increasing amounts of the pyroxenic component.

In recasting the analyses some important assumptions were necessary, which do not materially change the results. Thus when water was not determined in parts above and below 110 C. it was arbitrarily divided into combined and absorbed. Fe_2O_3, which in nos. 1 and 4 includes some FeO, was broken up so as to give magnetite. In no. 1 after the best possible combination of oxids, 1.122 Al_2O_3 remained, and in no. 3, the SiO_2 failed to satisfy its natural associates by 2.40. There were probably some slight errors in determinations, for there seems no escape from the mineralogical compositions used. In no. 5 the most basic one and obviously well over toward the gabbros, the recast values are taken from results given by Professor Cushing and involve no kaolin.

The results show that quartz may be expected in the moderately silicious ones although it may not be sufficiently abundant to catch the eye of the observer. The orthoclase molecule is also seldom visible in the slides. The plagioclase lies near the labradorite series but when the anorthite molecule passes the 2. ratio it approximates bytownite. The overwhelming percentage of the feldspar is apparent. The anorthosites are rich in the light colored minerals beyond the vast majority of eruptive rocks. To what extent the ferromagnesian molecules are to be assigned to diopside and hypersthene is not apparent. Microscopic study proves both to be present but their total is small at best.

We have thus to deal with a great eruptive magma, containing little else than silica, alumina, lime and soda. Although the first to appear in a series it is probably a differentiation product from an earlier original richer in iron and magnesia. The later residual outbreaks profited by these accumulated bases which were left behind.

Inclusions. In the bare ledges along Coughlin and Stevens brooks which flow eastward down the eastern buttress of Giant mountain several cases of included fragments of older rocks, undoubtedly belonging to the Grenville series have been discovered. Figure 4 illustrates the shape and size of one. They have uniformly a garnetiferous border marking their boundaries against

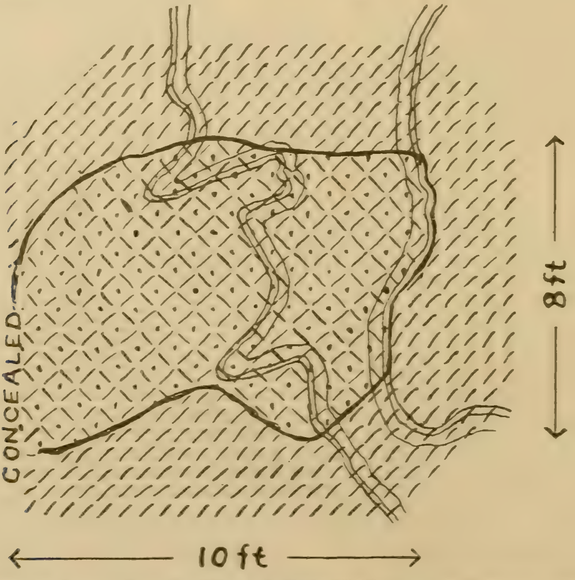

Fig. 4 Fragment of quartzite, included in anorthosite. Bed of Coughlin brook, about 1 mile west of highway.

the anorthosite. They themselves are chiefly a mixture of quartz and diopside. Each of these minerals makes up about half of the slide, the only additional component being a small grain of apatite. The crystals range up to 2 millimeters in diameter. The diopside is of irregular outline, of a pale green color, with slight pleochroism to yellow. The quartz is strained around the edges, and in one slide is cloudy at the center of the crystals because of innumerable, minute acicular inclusions, probably rutile, and oriented in every direction. Presumably the original rock was a quartzose and somewhat calcareous clastic, which on recrystallization has afforded the minerals described. The edges of the inclusion, being melted into the more calcareous anorthosite yielded the garnet rims.

Rocks of this composition are well recognized members of the Grenville, and have been described by H. P. Cushing under the name of quartz-diopside rock in Museum Bulletin 115, pages 504–8. To the unaided eye they resemble coarsely crystalline quartzites and as such were collected in the field. The best explanation of these curious masses of rock is the one which refers them to original Grenville strata pierced by the intrusive anorthosite, which tore off and included fragments and did not entirely absorb them.

Border facies of anorthosite. Around the borders of the main great intrusion, the anorthosites in this as in neighboring areas take on more dark silicates and lose also the distinctive bluish or greenish color of the feldspar, which is quite characteristic of the central portions. Professor Cushing has observed the same feature in the Long Lake area,[1] and has given it a special color on his map.

Several years ago while in the field upon the Lake Placid quadrangle, this feature was noted in the rocks of Whiteface mountain and in the notes the rock was called the Whiteface type. A sample from the summit of this mountain was analyzed by George Steiger in the laboratory of the United States Geological Survey with the results given below. The feldspar of the rock is white and shows evidence of crushing and granulation. The dark silicates are much more abundant than in the typical anorthosite and besides the pyroxenic minerals, diopside and hypersthene, hornblende is frequent.

This same type of rock has been noted northeast and east of New Russia and it forms a small prong of Oak hill.

The Whiteface type has a medium percentage of silica as the anorthositic rocks run. There are other varieties with somewhat

[1] N. Y. State Mus. Bul. 115, p. 473.

more silica and yet with nearly 15 per cent of dark silicates and still others with less and larger percentages of the ferromagnesian minerals. In the first two analyses given below, no. 1 and no. 3 are probably not separate intrusions from the main anorthosite mass but merely more ferromagnesian phases. No. 2, the Whiteface type, is interpreted in the same way. It is not easy in these cases to decide whether we are dealing with a separate intrusive mass of mineralogy closely related, or not. Irruptive contacts against the anorthosites have not been discovered and the location of these varieties around the borders of the main mass leads to the interpretation of them as rim facies.

There are, however, at least two cases in which intrusive relations to the anorthosites can be demonstrated in more basic rocks but ones of different type from the distinctively basic gabbros. In the one case included fragments of anorthosite have been discovered in the mass of gabbro; in the other irruptive contacts are displayed. In both instances gneissoid structures have been subsequently induced by pressure.

	1 Pyroxenic anorthosite, Elizabethtown	2 Pyroxenic anorthosite, summit of Mt Whiteface	3 Pyroxenic anorthosite, Giant trail, Keene valley
SiO_2	56.94	53.18	52.37
Al_2O_3	20.82	23.25	24.68
Fe_2O_3	.83	1.53	1.24
FeO	3.02	1.82	3.49
MgO	2.36	2.60	2.00
CaO	9.41	11.18	10.57
Na_2O	3.36	3.97	4.02
K_2O	1.58	.86	.86
H_2O+	.59	.98	.90
H_2O-	.21	.15	....
CO_2	.45	.34	....
TiO_2	.44	.45	....
S	....	tr	....
P_2O_5	.07	.09	....
MnO	.11	.11	....
BaO	.05	....	....
	100.24	100.51	100.13
Quartz	7.20		Deficit .90
Orthoclase	9.45	5.00	5.00
Plagioclase	61.10	69.12	80.52
	$Ab_1An_{2.2}$	Ab_1An_2	$Ab_1An_{2.84}$
Pyroxenes	14.84	15.36	12.86
Apatite	....	.21	....

	1 Pyroxenic anorthosite, Elizabethtown	2 Pyroxenic anorthosite, summit of Mt Whiteface	3 Pyroxenic anorthosite, Giant trail, Keene valley
Magnetite	1.16	2.09	1.62
Titanite	1.00	.99	....
Calcite	1.00	.80	....
Kaolin	4.39	6.97	....
Total	100.14	100.54	100.90
Light colored minerals	83.14	81.89	85.52
Dark colored minerals	17.00	18.65	14.48

No. 1. Pyroxenic anorthosite from the Woolen Mill, 1 mile west of Elizabethtown. Analysis by W. F. Hillebrand in the laboratories of the United States Geological Survey.

No. 2. Pyroxenic anorthosite summit of Mt Whiteface. Lake Placid quadrangle. Analysis by George Steiger in the laboratories of the United States Geological Survey.

No. 3. Pyroxenic anorthosite, High fall, Giant trail, Mt Marcy quadrangle. Analysis by C. A. Jouet. Department of Chemistry, Columbia University.

The analyses are arranged according to the decreasing percentages of silica. As the recalculation shows, lower silica does not necessarily imply higher percentages of the pyroxenic constituents since no. 3, the lowest in silica, has the highest percentage of feldspar and the lowest of the dark mineral. Its feldspar is, however, the most basic of all, being within the bytownite ranges.

In the quantitative system all three fall within class II, Dosalane, order 4, Germanase, rang 4, Docalcic, Hessase, subrang 3, Persodic Hessose.

Intermediate gabbros demonstrably later than the anorthosites

Special interest attaches to the two members of this variety which have afforded evidence of the relative periods of intrusion. In the case first cited, the succession has been shown by included masses; in the second instance, the irruptive contact can be followed for over a hundred yards in the rocky bed of a brook, fortunately in a very accessible locality. The two cases will be described under locality names as the Split Rock falls, and the Woolen Mill.

Split Rock falls locality. In the valley of the Boquet river and south of New Russia there is an intrusive mass which covers 5 or 6 square miles and which is distinct from the anorthosites of the

mountains to the westward. It outcrops in typical development at Split Rock falls, where in the cascades of the Boquet it is well

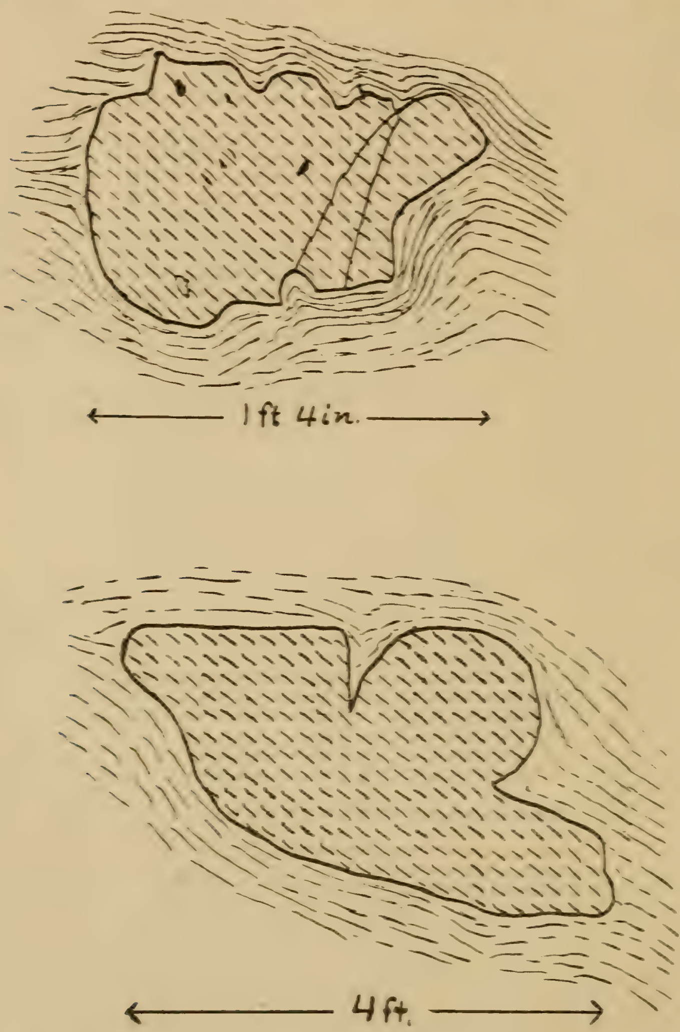

Fig. 5 Two inclusions of anorthosite in Split Rock Falls type, at Split Rock falls

exposed. The rock is suggestive of the anorthosites in that blue labradorite is the chief feldspar present, but the dark silicates are more abundant and when crushed and sheared the rock yields a decidedly foliated gneiss. It then becomes a hard dense rock, extremely tough. Nevertheless, large phenocrysts of labradorite are

not uncommon and the gneiss often exhibits the "augen" produced from them.

Fig. 6 Inclusions of anorthosite in gabbro of the Split Rock Falls type. Ledges on Slide brook

This intrusive is known to be later than the anorthosites because in the bare ledges along the cascades at Split Rock falls, inclusions of anorthosite are found in it. Each is surrounded by a garnet rim which appears to represent magmatic or corrosion phenomena.

Woolen Mill locality. On the south side of the Branch a mile to the west of Elizabethtown and near the mill there is a very interesting rock which exhibits an irruptive contact with the anorthosite and extends both westward and southward. It is dark, gneissoid and of moderate coarseness of grain. It resembles a rather basic member of the syenite series but has occasional blue labradorite phenocrysts which ally it with the anorthosites. Under the microscope and in slides from specimens without the labradorite phenocrysts, the minerals are, rather deep green pyroxene, sometimes showing faint pleochroism to yellow, plagioclase, ortho-

clase, quartz, garnet, magnetite and pyrrhotite as the chief components. Apatite of course appears in occasional crystals, and biotite is moderately frequent at times and again rare. The same is true of hornblende. The individuals, except for the rare phenocrysts rarely reach 1 millimeter in diameter, ranging from .25 to .5 millimeter. They are irregular in shape so that the rock is finely granitoid in texture. It is rather dark gray in color and is strongly contrasted with the anorthosite against which it lies. The rock has undoubtedly been granulated to an appreciable degree by pressure and crushing. The edges of the components frequently show strains under crossed nicols.

Two analyses have been prepared of the gabbro, one from a locality just below the dam at the mill, no. 2; and the other, no. 3, of a more acidic phase farther up stream. No. 2 is by Dr W. F. Hillebrand and was made in the laboratories of the United States Geological Survey; no. 3 is by Dr C. A. Jouet in the laboratories of Columbia University. No. 1 is the anorthosite and is repeated from p. 36.

	1	2	3
SiO_2	56.94	47.16	50.54
Al_2O_3	20.82	14.45	21.28
Fe_2O_3	.83	1.61	3.43
FeO	3.02	13.81	8.73
MgO	2.36	5.24	2.08
CaO	9.41	8.13	8.72
Na_2O	3.36	3.09	2.95
K_2O	1.58	1.20	1.63
H_2O+	.59	.48	.35
H_2O-	.21	.12	.06
CO_2	.45	.35	present
TiO_2	.44	3.37	....
P_2O_5	.07	.57	....
MnO	.11	.24	.40
BaO	.05	....	....
S	....	.14	.64
NiO CoO	....	.02	....
	100.24	99.98	100.81

	1	2	3
Quartz	7.20	....	3.60
Or	9.45	7.23	7.23
Ab	28.30	26.20	25.15
An	32.80	18.07	27.80
Kaolin	4.39	3.43	2.58
Calcite	1.00	.80	....

	1	2	3	
$CaO.SiO_2$	4.06	6.96	2.90	Augite and Hypersthene
$MgO.SiO_2$	5.90	5.40	4.10	
$FeO.SiO_2$	4.88	7.13	5.28	
$MnO.SiO_2$	....	.40	.66	
$MgO.Al_2O_3.SiO_2$	....	....	1.41	
$FeO.Al_2O_3.SiO_2$	....	....	1.64	
$K_2O.Al_2O_3.2SiO_2$	....	....	1.26	Biotite
$2MgO.SiO_2$	....	....	.56	
$2FeO.SiO_2$	....	....	.82	
$3CaO.Al_2O_3.3SiO_2$	....	....	4.50	Garnet
$3FeO.Al_2O_3.3SiO_2$	....	....	4.98	
$2MgO.SiO_2$	....	5.46	....	
$2FeO.SiO_2$	....	8.36	....	
Magnetite	1.16	2.32	4.87	
Ilmenite	....	6.23	....	
Apatite	....	1.34	....	
Pyrrhotite	....	.35	1.65	
H_2O—	....	.12	.06	
Ilmenite	1.00	....	....	
Total	100.14	99.80	101.05	
	$Ab_1An_{2.2}$	$Ab_1An_{1.3}$	Ab_1An_2	
Light colored minerals	83.14	55.73	66.36	
Dark colored minerals	17.00	43.95	34.63	

In the quantitative system, nos. 1 and 3 are both in class II, Dosalane, order 5, Germanase, rang 4, Docalcic, Hessose and subrang 3, Persodic, Hessose. No. 2 comes under class III, Salfemane, order 5, Gallase, rang 4, Docalcic, Auvergnase, subrang 3, Auvergnose.

The recasting of no. 1 presents no difficulties; the calculated results correspond closely with the observed minerals, with the possible reservation that the quartz does not impress one as being so abundant in the slide. No. 2 is also not a difficult analysis to recast and still deal only with observed minerals. The only surprising feature is that the relatively small percentage of alumina restricts the possibilities of the anorthite molecule and leads to a variety of plagioclase, $Ab_1An_{1.3}$, unexpectedly acidic for so basic a rock. It seems peculiar to have in the most basic of the three analyses the most acidic feldspar. In no. 3, the slides reveal a complicated mineralogy, since we have both biotite and garnet to deal with, and assumptions are unavoidable in the distribution of certain oxids. Thus there is slight opportunity for error in the pyrrhotite and albite. As regards the others, we are in doubt as to the division of the K_2O between the orthoclase and biotite, although it is evident from the slides that the greater part belongs with the

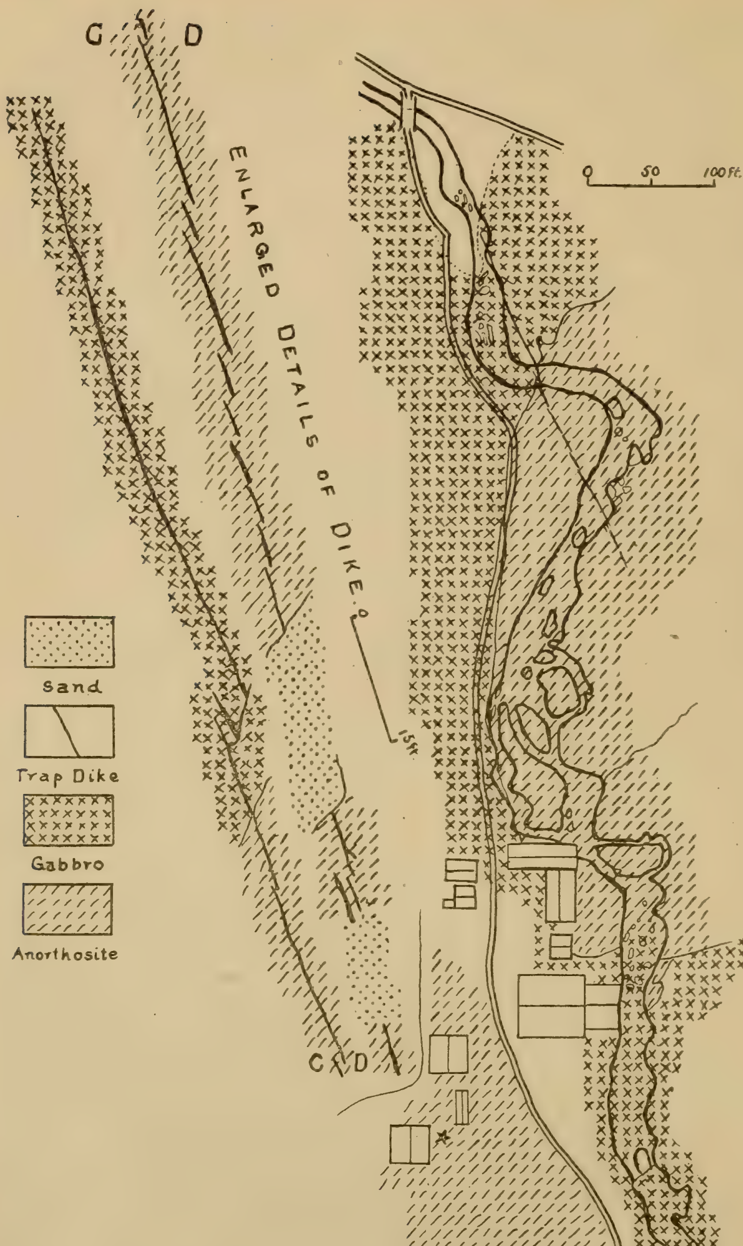

Fig. 7 Map showing irruptive contacts of the Woolen Mill type of gabbro and anorthosite. Both are cut by a basaltic dike. The "Branch" 1 mile west of Elizabethtown

former which is more abundant. There may be a little H_2O in the biotite, but it has all been assigned to kaolin. The division of the CaO among anorthite, pyroxene, garnet and possible hornblende is purely an estimate. In the recasting about two thirds the molecules were assigned to the anorthite, while the remainder were allotted to garnet and pyroxene (including hornblende). The FeO and MgO had to be divided between biotite (a relatively small portion) and pyroxene (hornblende). Some FeO was also used for garnet. There is more than enough Al_2O_3 for the feldspar, biotite and garnet, so that a small residue was placed in the pyroxene as is doubtess justifiable. All the Fe_2O_3 was used for magnetite, as this assumption did not yield any more than is obviously present in the slides. The composition of the garnet was necessarily assumed to involve both the grossularite and the almandite molecules. There is probably a little TiO_2 in the rock but if so it is presumably in the magnetite for no titanite worth mention was observed. After all these assumptions, suggested or checked by estimates of the relative abundance of the minerals as seen under the microscope, the above result was reached. It is difficult to believe that a molten magma of only 50.54 per cent silica would crystallize directly from fusion so as to yield this excess of silica forming 3.60 of quartz. If we recast without using the garnet molecule and with the allotment as usual of all the alumina remaining above the orthoclase, albite and kaolin, to the anorthite, only a tenth as much or about .30 remain uncombined. The natural inference follows that the garnet has resulted from metamorphic reactions between the pyroxene and anorthite, in which the lime and alumina of the latter were utilized and the silica left free.

The Woolen Mill locality is not the only one for this variety of rock, or at least for one that to the eye appears to be the same. Blueberry mountain along the southern border shows the same general aspect with occasional large blue crystals of labradorite.

New Pond locality of a peculiar gabbro. Along the road leading into New pond and an eighth of a mile before it terminated at the pond itself, a ledge of a very peculiar eruptive was found, which differs from all others mentioned. It consists of sharply angular crystals of plagioclase, rectangular in cross section, imbedded in a dark green matrix of what proves under the microscope to be granules of augite. This rock has been seen in boulders within a mile or so of the locality mentioned and may be more widely distributed. It has also been seen in the Mt Marcy quadrangle along the highway about a half mile south of Beede's. The

affinities of the rock are rather with the anorthosites than with the basic gabbros.

The relations of this rock to the other eruptives and the sedimentaries have been nowhere shown as the exposures were so limited that no conclusion could be drawn. The rock is one admirably adapted to give pronounced horniblendic gneiss under shearing and stretching and it may have been the original of some of the puzzling gneisses occasionally seen in the region. Under metamorphism the augite would pass into hornblende and the relations of it to the feldspar are exactly those which would yield interleaved lenses when crushed and drawn out.

Syenite series

The syenitic series has been one of comparatively late recognition in Adirondack geology. The rocks were first identified as eruptives on the western side of the Archean area by C. H. Smyth.[1] Soon thereafter the significant exposures found by H. P. Cushing in the railway cut near Loon Lake station on the northern side demonstrated their intrusive relations with the Grenville.[2]

The writer has also noted briefly the occurrence of green gneisses in Ticonderoga which were suspected of being eruptive,[3] but it was only after an instructive trip with Professor Cushing to the Loon Lake occurrence that the identity of these rocks was demonstrated. At times they look much like anorthosites especially in their crushed and gneissoid phases, and again they have been classed with the supposed ancient gneisses. The series embraces variations from the typical composition of syenite but the minerals with minor additions are the same and there are intermediate phases. As components of the Adirondack area the syenites do not yield in importance, even to the anorthosites, and their recognition has served to remove a vast amount of hitherto puzzling rocks from the noncommittal designation "gneiss."

In typical and least altered form the syenite is a dark green massive rock, of moderate coarseness of grain. Its components

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[1] Smyth, C. H. jr. Crystalline Limestones and Associated Rocks of the Northwestern Adirondack Region. Geol. Soc. Am. Bul. 6. 1895. p. 271-83. Report on the Crystalline Rocks of the Western Adirondack Region. N. Y. State Geol. 17th An. Rep't, p. 472.

[2] Augite-syenite Gneiss near Loon Lake, N. Y. Geol. Soc. Am. Bul. 10. 1899. p. 177-92. Geology of the Northern Adirondack Region. N. Y. State Mus. Bul. 95. 1905. p. 312; Bul. 115. 1907. p. 512.

[3] Preliminary Report on the Geology of Essex County. N. Y. State Geol. An. Rep't for 1893. 1894. p. 452.

never reach the great sizes of the labradorites in the coarse anorthosites, but range not far from the dimensions of those of the ordinary granites. The green feldspar is the chief component but with it are dark silicates sometimes in relatively large amount. Quartz is not lacking entirely but can not often be seen by the unaided eye. The analyses which have been prepared especially in connection with Professor Cushing's work show percentages in silica which usually range between 60 and 65 or under those of typical granite but there are close relatives both above and below these values. The potash and soda are generally present in nearly equal amounts.

The following analyses have been selected to illustrate the run of composition. None are based on samples taken in the area covered by this bulletin, but they represent all sides of the Adirondack region, and undoubtedly could be duplicated in the former. Later analyses of a series from Mineville will be given, which depart in both directions from the compositions here cited. The Ticonderoga case, no. 5, is the nearest to the Elizabethtown and Port Henry quadrangles. The sample was taken near the railway crossing of the Lake George outlet and is about 15 miles from Port Henry. As soon as one examines these analyses, they are seen to be obviously closely akin. The low magnesia and the nearly balanced alkalies are striking.

ANALYSES OF SYENITES.

	1	2	3	4	5	6	7
SiO_2	68.50	66.72	64.47	63.45	62.41	61.01	59.70
Al_2O_3	14.69	16.15	10.51	18.38	18.75	15.36	19.52
Fe_2O_3	1.34	1.23	1.11	1.09	2.49	10.75	1.16
FeO	3.25	2.19	7.37	2.69	4.91		5.65
MgO	.26	.73	5.21	.35	.61	.78	.78
CaO	2.20	2.30	3.10	3.06	3.17	4.05	3.36

1 Quartz-augite syenite. Altamont, Franklin co. Analyzed by E. W Morley for H. P. Cushing. N. Y. State Mus. Bul. 115. 1907. p. 514.

2 Augite-syenite. Little Falls, Herkimer co. *Idem.*

3 Syenite, gneissoid. Whitehall, N. Y. Analysis by W. F. Hillebrand

4 Augite-syenite. Loon Lake, Franklin co. Analyzed by E. W. Morley for H. P. Cushing, who considers the occurrence as typical. Geol. Soc. Am. Bul. 10. 1900. p. 177. Revised in N. Y. State Mus. Bul. 115. 1907. p. 514.

5 Augite-syenite. Ticonderoga, Essex co. Analysis by M. K. Adams.

6 Augite-syenite. Altamont, Franklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

7 Augite-syenite. Line of townships 22 and 23. Franklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

	1	2	3	4	5	6	7
Na_2O	3.50	4.36	2.21	5.06	3.09	3.68	5.31
K_2O	5.90	5.66	3.63	5.15	4.25	3.90	4.14
H_2O+	......	......	.75	......	......	......	......
H_2O-	......	......	.18	......	......	......	......
H_2O	.40	.77	......	.30	.41	.49	.52
TiO_2	......	......	......	.07	......	......	......
P_2O_5	.03	......	.25	......	......	......	......
MnO	.10	.07	......	tr	......	.08	.09
BaO	.05	......	......	.13	......	......	......
S	......	......	.12	......	......	......	......
CO_2	......	......	.58	......	......	......	......
	100.22	100.18	99.49	99.73	100.09	100.10	100.23

1 Quartz-augite syenite. Altamont, Franklin co. Analyzed by E. W. Morley for H. P. Cushing. N. Y. State Mus. Bul. 115. 1907. p. 514.

2 Augite-syenite. Little Falls, Herkimer co. *Idem.*

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5 Augite-syenite. Ticonderoga, Essex co. Analysis by M. K. Adams.

6 Augite-syenite. Altamont, Fronklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

7 Augite-syenite. Line of townships 22 and 23. Franklin co. Analyzed by E. W. Morley for H. P. Cushing, as under no. 1.

In the quantitative system, nos. 1 and 2 fall under class I Persalane; order 4 Brittannare; rang 2 Toscanase; subrang 3 Toscanose.

Nos. 3 and 5 belong in class II Dosalane; order 4 Austrare; rang 2 Dacase; subrang 3 Adamellose.

No. 4 is in class I Persalane; order 5 Canadare; rang 2 Pulaskase; subrang 3 Pulaskose.

No. 7 is in the same except the subrang 4 Laurvikose.

No. 6 is in Class II Dosalane; order 4 Austrare; rang 3 Tonalase; subrang 3 Harzose.

Under the microscope the chief feldspar is at once seen to be microperthitic orthoclase; that is, the orthoclase of the ordinary syenites is filled with flattened, parallel blades or spindles of albite. This microperthite is very characteristic and with the beautiful emerald-green pyroxene affords one of the distinguishing features of this group of rocks. Plagioclase is not entirely lacking, and especially in the specimens from Mineville is at times quite prominent. Quartz is variable. As will be shown later there are phases, apparently differentiation products of the syenite magma, in which

it is very abundant, and the rock becomes a granite, or of granitic composition. In these the quartz is very abundant. Again in the basic extremes, it fails, and in the true syenite phases, the most characteristic of the series, it is rare or absent.

The most prominent of the dark minerals is a beautiful and striking emerald-green pyroxene. It has the high extinction angles of augite, and sometimes a faint pleochroism to yellow. Experience gained in recasting analyses leads to the conclusion that the jadeite molecule, Na_2O, Al_2O_3, $4SiO_2$, is present in its composition, and may be largely responsible for the beautiful green color, so suggestive of aegirite. The pyroxene often changes to chlorite and when present in the bodies of magnetite associated with the syenites, it yields red oxid of iron and stains the ore red by filtering into the cracks in the neighboring minerals. It has the same effect on the syenitic rocks, especially those associated with the ore. Under the miscroscope the reddish tinge can be traced back to the chloritized pyroxene.

Hypersthene is occasional in the syenites, but scarcely so abundant as to require extended description. Hornblende, however, is very common. It is a deep brown variety and in the basic types may be more abundant than pyroxene. Biotite is known but is subordinate. The basic phases have it more abundantly than the acidic. It is deep brown in color, but not otherwise remarkable.

Among the accessories titanite is sometimes extremely abundant. To the unassisted eye it might be taken for garnet, and in the acidic phases, associated with the magnetites, it makes this impression, but the microscope, of course, reveals its identity. Apatite is at times noticeably abundant but presents no peculiarities worthy of special remark. Zircon favors the acidic extremes. Magnetite is in all varieties, even the most acidic, where, unless sharply observed, it might be mistaken for a dark silicate. Pyrrhotite is rarely to be detected.

In earlier experience it was believed that garnet was practically limited to the anorthosites and basic gabbros, but as the tendency of the syenites to develop basic phases has been appreciated and the dark hornblendic gneisses have seemed to be, in part at least, referable to them, garnet has been recognized as one of their minerals. While the reaction rims, which will be more fully described under the basic gabbros, are far more abundant in these latter rocks, yet some cases have been observed in which they were also apparent in the syenitic gneisses. Some dark, hornblendic gneisses have, in the later field work, shown such relationship as to

be referable to the basic syenites and not necessarily to the gabbros, as formerly believed. Field associations and preponderance of orthoclase as seen under the microscope must hereafter decide.

On weathering, the syenitic rocks are particularly prone to develop a rusty exterior although just why the contained iron is in a condition so sensitive to alteration, is not apparent. When one seeks for a fresh hand specimen from fallen blocks, it is often necessary to pound off several inches or the better part of a foot before the fresh green rock appears at the core. Where polished off smooth and hard by glaciation, the rock may also develop a very white coat or skin which, however, is easily chipped off so as to expose the fresh green beneath.

The relative proportions of the several minerals vary widely over extended areas. Toward the acidic extreme, quartz may become increasingly abundant, fully enough to carry the rocks over into the granites. Such varieties appear on Barton hill near Mineville and in association with the ores of the great mines. Yet the microperthitic character of the feldspar is pronounced and the same augite and hornblende are in evidence which we find in the typical specimens, so that one can not well avoid the conclusion that there is a fundamental relationship.

Very instructive evidence has been afforded by the numerous diamond drill cores which have been obtained in the explorations for magnetite at Mineville. The writer has examined most carefully thousands of feet of these, and finds on the whole the average syenite most frequently present, but with no evidence of being a separate intrusive mass. The most acidic variety will quite sharply replace it; and in the same way a very basic variety may come in and constitute the section for 50 or 100 feet or more. Yet while the transition is sharp there is no evidence of separate intrusive masses nor is one justified in inferring more than a differentiation of an eruptive mass into layers or portions of contrasted composition. As will be later shown in speaking specially of the ores, the great body of magnetite lies immediately beneath the most acidic phase. The ore contains appreciable amounts of the emerald-green pyroxene and is simply an extremely basic concentration of one of the normal minerals, the magnetite, accompanied by two others, the pyroxene and apatite. Beneath the ore, usually if not always, is found a basic phase of the syenite. All these relationships will be more fully discussed from the standpoint of the ore on subsequent pages, the object being at the moment to emphasize the variability of the rock mass.

In the Ausable quadrangle very rusty basic dikes of the syenite series have been found, intrusive even in older and larger masses of the same series of rocks. The basic syenitic types develop under metamorphism a crumbling variety of gneiss, which on exposures that have been quite thoroughly weathered may be rubbed to coarse sand between the fingers. Black grains of silicates and ores then separate from rusty green feldspar.

Within the area here described all varieties of syenites show the effects of crushing and the production of gneissoid foliation to a marked degree and no locality can be cited free from it. Along fault planes, where dynamic effects are pronounced, much secondary quartz has sometimes been infiltrated and on weathering the rock becomes a pronounced red, looking like a coarse, red granite.

This so called syenite series has an exact parallel in Norway, where in association with anorthosites, practically indistinguishable from the Adirondack occurrences, C. F. Kolderup has established the existence of others consisting of microperthite and augite. The latter Kolderup calls by the new name mangerite, based on a Norwegian locality, Manger. This duplication on opposite sides of the Atlantic is an extremely interesting coincidence.[1]

The following analyses have been prepared of the syenites within the area covered by the bulletin, three of the samples having been taken from drill cores at Mineville. They represent the several varieties as well as selections would admit. With them is also placed one of a marked granitic phase, no. 1, which, however, careful study of relationships fails to prove a separate intrusive mass.

	1	2	3	4
SiO_2	68.87	73.84	52.01	45.81
Al_2O_3	10.76	14.11	16.93	20.32
Fe_2O_3	3.52	.22	.14	.53
FeO	1.26	1.12	10.25	8.45
MgO	2.27	.83	2.50	6.45
CaO	2.59	.44	6.14	7.97
Na_2O	2.45	6.36	4.65	4.53

1 Granitic extreme of syenite series 1 mile west of Mineville. Analyzed by Charles Fulton.

2 Granitic extreme of syenite series; hanging wall of magnetite. Mineville. Analyzed by M. K. Adams.

3 Average syenite of rocks containing the Mineville magnetite. M. K. Adams.

4 Basic syenite of rocks containing the Mineville magnetite. M. K. Adams.

[1] Kolderup, C. F. Die Labradorfelsen des westlichen Norwegens. Bergen's Museum's Aarbog. 1903. p. 102.

	1	2	3	4
K_2O	7.88	2.38	2.54	1.58
H_2O+	....	.46	.45	.60
H_2O-	....	.11	.02	.03
CO_2	....	.16	none	none
TiO_2	.14	.46	3.00	2.34
ZrO	....	.09	none	none
P_2O_5	....	.06	1.24	.53
S	....	.07	.27	.22
MnO	....	.03	.21	.15
BaO	....	none	tr	.02
Cr_2O_3	....	none	none	none
	....	100.74	100.35	99.53
O-S	....	.03	.10	.09
Total	99.74	100.71	100.25	99.44

	1	2	3
Quartz	21.540	24.540	....
Orthoclase	36.696	13.344	14.456
Albite	20.960	53.448	39.300
Kaolin	....	3.096	3.096
Calcite	....	.200	....
Titanite	.198	1.188	7.128
Zircon	....	.182	....
$CaO.SiO_2$	5.336	....	5.336
$MgO.SiO_2$	3.800	2.100	.900
$MgO.Al_2O_3.SiO_2$	....	....	1.616
$FeO.SiO_2$	1.848	1.716	17.688
$MnO.SiO_2$	....	....	.393
$2(K_2O.Fe_2O_3.2SiO_2)$	6.732	....	....
$2MgO.SiO_2$	1.260	....	....
Magnetite	.928	.232	.232
$MgO.Al_2O_3$	....	....	6.390
Pyrrhotite	....	.120	.480
Apatite	....	....	3.016
P_2O_5	....	.060	....
CO_2 excess	....	.044	....
H_2O-	....	.110	....
MnO	....	.030	....
Total	99.298	100.410	100.031

1 Granitic extreme of syenite series 1 mile west of Mineville. Analyzed by Charles Fulton.

2 Granitic extreme of syenite series; hanging wall of magnetite. Mineville. Analyzed by M. K. Adams.

3 Average syenite of rocks containing the Mineville magnetite. M. K. Adams.

4 Basic syenite of rocks containing the Mineville magnetite. M. K. Adams.

Endeavors to recast these analyses according to the mineralogy exhibited by the thin sections have not been very satisfactory.

No. 1 has involved several assumptions. The soda was first all assigned to albite. The remaining alumina was used for orthoclase, there being none for anorthite. The residue of potash, with the necessary ferric iron, was used for biotite, affording a variety abnormally high in the alkali but making very little difference in the gross result. Everything else was assigned to hornblende, except for the little magnetite and titanite. The slides reveal quartz, microperthite, biotite, hornblende, magnetite and zircon.

No. 2 presents no difficulties. The great preponderance of the light colored minerals is striking, since about 95 per cent consist of these. The remainder is chiefly augite although this mineral is a very obscure component to the eye. The richness in the albite molecule is striking. While this mineral is chiefly observed in microperthite, it can not obviously be altogether in this form, since 13 per cent orthoclase could hardly contain 53 per cent albite. While this rock is believed to be an acidic differentiation product from the syenitic magma, it is only fair to state that in one respect the analysis is similar to the usual run of slates and argillaceous sandstones, in that with high silica the magnesia exceeds the lime. The opposite relation usually holds for the eruptive rocks. Yet the amounts are small and other considerations lead to the interpretation as an igneous variety. The presence of zircon in the acid member and its failure in the basic is an interesting corroboration of our ordinary conceptions of the home of this mineral.

When the recasting of nos. 2, 3 and 4 are undertaken, difficulties arise in providing so much soda with sufficient silica to satisfy the albite molecule, at its ratio of one soda to six silica and yet have sufficient silica left to form unisilicates which take up the other bases. One can not but infer that the emerald-green pyroxene itself carries soda, but it can not be in the form of the acmite molecule, $Na_2O.Fe_2O_34SiO_2$ since we have so little Fe_2O_3, while magnetite is a certain component of the rock. The alumina is also in excess, and can only be provided for by the spinel molecule. Yet no spinel has been detected in the slides. Any form of the olivine molecule, and any corundum which we would use according to the methods of the "Quantitative System of Classification of Igneous Rocks" are also not to be observed in the slides. Nephelite can also not be detected in the slides although with basic rocks such as these, the rather high percentage of soda would seem to call for it.

The chemical analyses also throw some light on the question of their igneous or sedimentary nature. It will be observed that all the rocks are rich in soda, even the most basic. Were they recrystallized sediments, they must have been derived from shales, or in the most acidic cases, shaly sandstones, since no other sediments will give anything approximating these compositions. Yet in the process of disintegration of feldspathic rocks and deposition of the debris as sediments, the alkalies diminish greatly and of the two, potash is customarily the survivor. Sediments of a composition such as these analyses afford, would be extraordinary, whereas eruptive rocks not infrequently furnish parallels.

Granite. This rock as an acidic extreme of the syenite series has already been referred to. The field relationships of the specimen analyzed are best explained by this assumption. In the southeastern corner of the Elizabethtown quadrangle, there is, however, as already set forth a quite extended area in which granitic rocks are prominent. It has been mapped as a separate mass, although the evidence of its individual intrusive character is not clear. The subject is fully discussed under the topic of granites and related types. They have a widespread reddish color and yield percentages in quartz such as are possessed by the granites.

In one of the two localities which have been studied with the microscope the rock consisted of quartz and microperthite in great preponderance. There were a few shreds of biotite and hornblende, and rarely a grain of magnetite and a zircon. The rock was greatly crushed and strained. This is the specimen which furnished the analysis given as no. 1 under the syenites above.

A second, a reddish rock from the southeastern corner of the Elizabethtown sheet in the area mapped as granite, contained greatly predominating quartz and finely twinned plagioclase. It has already been mentioned under granites on a preceding page. Orthoclase could not be identified. A few decomposition products, believed to have once been bisillicates, and a few tiny zircons made up the slide. The minerals showed abundant evidence of strains and crushing.

Basic gabbros

This type of rock constitutes a large number of intrusions well distributed along the border of the anorthosites and the other rocks and sometimes in the anorthosites themselves. They are widespread throughout the eastern Adirondacks and, although far less large in amount than the anorthosites and syenites, are yet a characteristic feature of the local geology. They appear chiefly as

irregular masses of moderate size, and are sometimes demonstrably in dikes. More often they seem to be irregular, eroded sheets, knobs, or perhaps laccoliths. The abundant vegetation, the widespread faulting, the extended erosion and the metamorphism, have all served to mask the details.

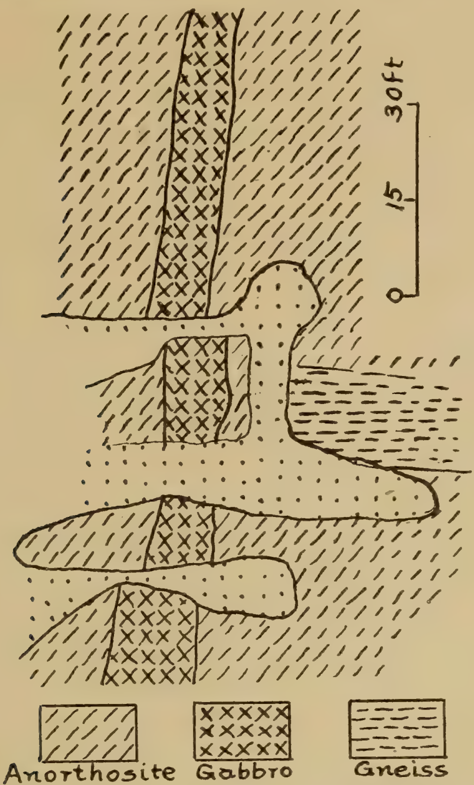

Fig. 8 Gabbro dike intruded in anorthosite and faulted. The gneiss is either an inclusion or a dike older than the gabbro, and greatly sheared. The locality is in Lewis in the northeast corner of Elizabethtown quadrangle.

The rocks are greenish black in color and rough upon weathered surfaces. The pitting from the decay and disappearance of the feldspar has left the augite and ever present magnetite projecting in little lumps. Where the gabbros appear in the beds of streams and beneath cascades, the rock is a rich green and affords most beautiful and instructive exhibitions of rock texture. It is comparatively rare that the gabbros are free from the effects of crushing and shearing. When, however, such specimens are found they present a coarse diabasic texture. The plagioclase crystals are tabular and on the fractured surfaces exhibit thin rectangular cross sections within whose network the dark silicates and the iron ores

are packed away. The ever present effects of pressure have almost always granulated the components and have turned feldspars, bisilicates and ores into lenticular interwoven masses. More complete crushing, often accompanied by apparent flowage, has given swirling, gneissoid foliation and in the extreme has developed a decided hornblendic gneis.. This curious and interesting variation of texture can be seen in the brook bottoms which enter the Boquet from the steep mountains on the west, and above Elizabethtown. The brook which comes in about 2 miles south of the village and along the contact of the gabbro and syenite and with a trap dike across its exit from the cliffs, gives very interesting exposures, and the same is true of Roaring brook a mile to a mile and a half from its mouth. The stringing out of the minerals may be in part a phenomenon of igneous flowage, but certain it is, that the textures vary greatly within short distances and the rock, whether molten or whether viscous from pressure, has not behaved as a perfectly hydrostatic body. Buttresses or masses unaffected by the flowage have remained in the midst of the generally plastic material.

The component minerals of the gabbro are chiefly plagioclase, augite, hypersthene, brown hornblende and titaniferous magnetite. The less common ones are olivine and biotite. A widespread member not truly original with the rock is garnet, which appears in the reaction rims in a very interesting and at times remarkable manner.

The plagioclase is a basic variety, labradorite or one even lower in silica. It is so charged with finely divided dusty inclusions that it remains practically opaque in its central portions even in very thin slides. The inclusions appear to be pyroxenic dust and minute green spinels, but they are so exceedingly small, and their optical properties are so disguised by the containing feldspar, that their sharp identity can not well be made out. Around the edges the feldspars become clearer, and next the reaction rims of garnet they are limpid and transparent and apparently are untwinned albite. The lime component seems to have been contributed to the garnet.

The augite is, in the thin sections, light green in color and appears to be of the ordinary variety, often seen in the gabbros. The hypersthene is widespread and frequently in sufficient amount to make the rock a norite. It is in no way remarkable. The hornblende is of a deep brown variety, and increases greatly in amount where metamorphism is more pronounced. Olivine is not specially abundant. So far as studied, many exposures may entirely fail to show it. It is pale green in color and customarily quite fresh. The titaniferous magnetite is richly distributed through the rock. It can be readily detected with the eye, and under the microscope

forms basic centers around which are grouped the bisilicates in especial richness. In several places the titaniferous magnetite has become sufficiently concentrated to attract attention as an iron ore. The ore yields about 40 per cent iron more or less, and can be best discussed under the topic iron ores. It is simply a portion of the gabbro mass with an unusual amount of the titaniferous magnetite. The feldspar fails but all the other components are distributed through the ore and appear in the thin section.

The reaction rims of garnet are very widespread in the gabbros, so much so that it is unusual to find the rock unprovided with them. They follow along the border lines between the feldspar and the more basic minerals, preventing the contact of the two, and giving a pinkish cast to the rock which is quite characteristic. The garnets at times manifest a curious tendency to develop projections like fingers out into the feldspar and seem to have formed from one twin lamella and not from those on either side.

A number of analyses of the gabbros were prepared several years ago in the laboratory of the United States Geological Survey, in connection with a paper by the writer, upon the "Titaniferous Ores of the Adirondacks."[1] They are reproduced here in order to give an idea of the chemical composition of the rock and to furnish a basis for recasting into the approximate percentages of component minerals. With these quoted analyses are one or two others from exposures not connected with ore bodies and only hitherto published in Bulletin 168, United States Geological Survey, page 37 under the work of the chemical and physical laboratories.

	1	2	3	4	5
SiO_2	47.88	47.16	46.74	44.97	44.77
Al_2O_3	18.90	14.45	16.63	15.40	12.46
Fe_2O_3	1.39	1.61	2.17	2.29	4.63
FeO	10.45	13.81	10.60	12.39	12.99
MgO	7.10	5.24	6.11	10.89	5.34
CaO	8.36	8.13	8.66	7.50	10.20
Na_2O	2.75	3.09	3.81	3.02	2.47
K_2O	.81	1.20	.86	.56	.95
H_2O—	.43	.48	.73	.65	.48
H_2O—	.18	.12	.12	.10	.12
CO_2	.12	.35	.07	.23	.37
TiO_2	1.20	3.37	2.54	1.18	5.26
P_2O_5	.20	.57	.33	.14	.28
S	.07	.14	.11	.06	.26
MnO	.16	.24	.26	.22	.17
NiO.CoO	.02	.02	.03	.02	......
V_2O_5		......	....	.02	......
	100.02	99.98	99.77	99.72	100.75

1 Wall rock of titaniferous magnetite. Split Rock mine, Westport. Analysis by W. F. Hillebrand.

2 Woolen mill 1 mile west of Elizabethtown. Analysis by W. F. Hillebrand. See above p. 40.

3 Gneissoid gabbro, 2 miles south of Elizabethtown. Analysis by W. F. Hillebrand.

4 Massive gabbro, same exposure as No. 3. Analysis by W. F. Hillebrand.

5 Wall rock of titaniferous magnetite. Lincoln Pond. Analysis by George Steiger.

[1] 19th An. Rep't. 1899. pt III. p. 377–422.

	1		2		3		4		5	
Or	4.45		7.23		5.00		3.34		5.00	
Ab	23.06	56.70	26.20	44.27	31.07	45.87	25.15	38.49	20.96	37.36
An	33.64		18.07		13.90		13.34		16.40	
Kaolin	3.10		3.43		5.42		4.65		3.60	
Calcite	.20		.80		.10		.50		.90	
$CaO.SiO_2$	2.67	13.41	6.96	19.89	11.25	11.98	3.48	6.66	12.53	32.71
$FeO.SiO_2$	4.88		7.13		.....		1.19		8.32	
$MgO.SiO_2$	5.60		5.40		.20		1.60		11.60	
$MnO.SiO_2$	.26		.40		.53		.39		.26	
$2FeO.SiO_2$	8.46	16.93	8.36	13.82	10.20	19.16	13.67	30.47	1.73	2.93
$2MgO.SiO_2$	8.47		5.46		8.96		16.80		1.20	
Magnetite	2.09		2.32		3.25		3.25		6.73	
Ilmenite	2.13		6.23		4.62		2.16		9.73	
Apatite	.34		1.34		.70		.35		.67	
Pyrrhotite	.18		.35		.26		.18		.65	
Garnet	.....		.....		.....		7.20		.....	
Spinel	.....		.....		3.13		2.13		.....	

	1	2	3	4	5
Plagioclase	$Ab_1An_{.3}$	$Ab_1An_{1.3}$	$Ab_1An_{0.8}$	Ab_1An_1	$Ab_1An_{1.5}$
Light colored minerals	64.45	55.73	56.39	46.98	46.86
Dark colored minerals	35.08	43.95	43.10	52.40	53.42

1 Wall rock of titaniferous magnetite. Split Rock mine, Westport. Analysis by W. F. Hillebrand.
2 Woolen mill 1 mile west of Elizabethtown. Analysis by W. F. Hillebrand. See above p.40.
3 Gneissoid gabbro, 2 miles south of Elizabethtown. Analysis by W. F. Hillebrand.
4 Massive gabbro, same exposure as no. 3. Analysis by W. F. Hillebrand.
5 Wall rock of titaniferous magnetite. Lincoln pond. Analysis by George Steiger.

In the quantitative system, no. 1 is class II Dosalane; order 5 Germanare; rang 4 Docalcic, Hessase; subrang 3 Persodic, Hessose.

Nos. 2, 3, 4 and 5 are all class III Salfemane; order 5 Gallare; rang 4 Docalcic, Auvergnase; subrang 3 Auvergnose.

In recasting the above analyses, nos. 1, 2 and 5 could be done in the normal way. That is, aside from the accessories such as magnetite, apatite, pyrrhotite, ilmenite and calcite about which there can be little doubt, the soda and potash were assigned to albite and orthoclase; the combined water to kaolin, and the remaining alumina used for anorthite. There then remained sufficient silica to care for the excess of lime as the bisilicate and for the ferrous iron and magnesia partly as unisilicates, partly as bisilicates. In nos. 3 and 4 this proved impossible, because if this course is followed for anorthite there is not enough silica to satisfy the remaining bases even as unisilicates which we know are not the sole dark silicates present. To obtain sufficient silica, the only feasible course was to reduce the anorthite, and for no. 3 a plagioclase molecule $Ab_1An_{0.8}$ was assumed. It became possible then to reach a solution. In no. 4 similarly Ab_1An_1 was assumed, and both the garnet and spinel molecules were called in. These assumptions have no particular advantage over the ordinary calculations of the highly ingenious quantitative system, except that we confine ourselves to making assumptions of minerals known to exist in the rock. Probably every one of these rocks had some garnet, to whose substance both anorthite and bisilicates contributed. Possibly

some of the ferric iron was in the bisilicates and it was not entirely combined in the magnetite. The calculation of the pyroxene does not tell us how much is hypersthene and how much is in the monoclinic variety. Probably some little alumina was in the pyroxene. Yet even with all these restrictions the final results in nos. 1, 2 and 5 are doubtless very near the truth and afford interesting general conclusions. Thus no. 1 is only 3 per cent higher in silica than no. 5. Yet the light colored minerals are almost 20 per cent greater in the former than in the latter. The excess of alumina in no. 1 is mainly responsible for this result, since by this we are able to care the better for lime in anorthite. It is striking that silica should fail to satisfy the bases in nos. 3 and 4 on the lines of the ordinary silicates, despite the fact that in these rocks its percentage exceeds that of no. 5, and but slightly yields to nos. 1 and 2. Mineralogical relationships in rocks, as indeed we have learned forcibly from the quantitative system, depend on other factors than the silica.

With all their shortcomings these recast analyses are nevertheless presented with the purpose of illustrating again the connection between chemical composition and mineralogical components.

Unmetamorphosed basaltic dikes

The last manifestation of eruptive activity and one which followed the general metamorphism, took the form of comparatively narrow basaltic dikes. They are quite widely distributed but not specially abundant in this area. They are members of an eruptive series which is widespread throughout the eastern and northern Adirondacks. Approximately 20 individuals or groups of individuals have been noted in the Elizabethtown quadrangle, and 16 in the Port Henry. These are undoubtedly but a small fraction of those existing and either concealed or unnoted. Wherever cascades reveal exposures for relatively long distances or iron mines have opened up the rocks underground the dikes have almost invariably been discovered. The great majority strike northeast. Of 32 accurate records, 19 lie between n. 35° e. and n. 70° e.; 6 are east and west and 4 nearly north and south. Only 3 are northwest. The northeast strike corresponds with the major structural breaks, and the dikes often appear in the broken and jointed rocks where exposed in the beds of brooks.

The dikes are mostly narrow, from 1 to 4 feet, but one has been met at 40 feet, and at the other extreme there are some only a few inches. Where the dikes tongue out to a feather edge, they

become a coaly black glass from the effects of chill, and always the borders are denser than the centers. One very interesting case has

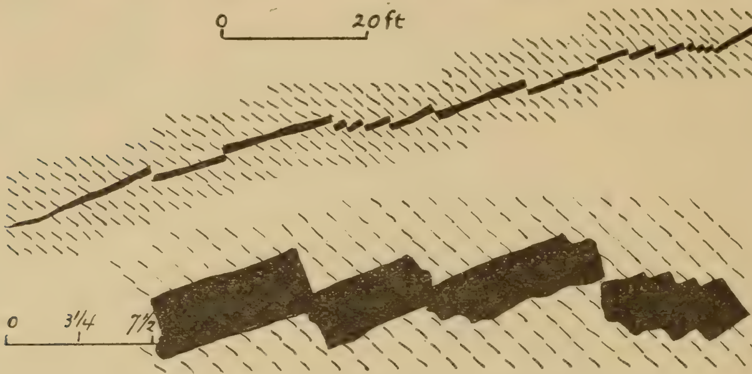

Fig. 9 Step-faulted dike in Walker brook, North Hudson

been found of one dike penetrating another and chilled by it. There were clearly two periods of intrusion in this instance and

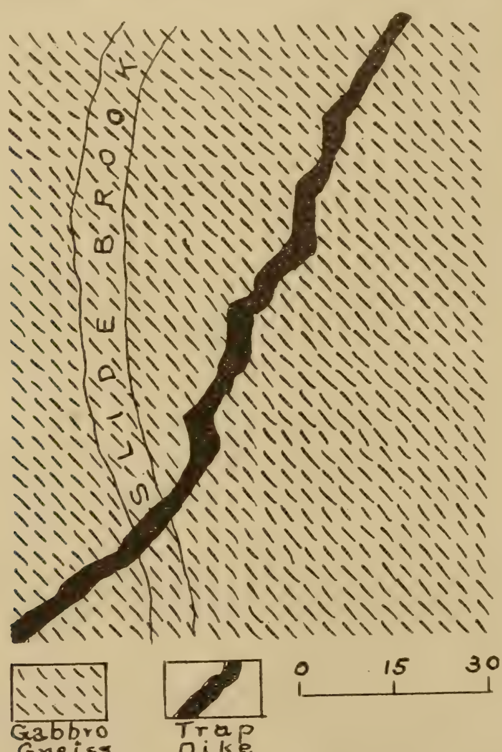

Fig. 10 Basaltic dike in an irregular and jagged crack on Slide brook. The dike strikes n. 15° e. and dips 10° east. The wall rock is gabbro of the Split Rock Falls type.

one followed long enough after the other to have permitted the first to quite thoroughly cool. The specimen came from a boulder in the bed of the Branch, 2½ miles west of Elizabethtown.

The dikes sometimes present extremely interesting exposures. Figure 9 was sketched in the north fork of Walker brook in the extreme southwest corner of the Elizabethtown sheet. It shows some very striking little faulted blocks of a dike in anorthosite. Presumably the dike was once continuous but in being broken and separated into the little blocks it held its sharply angular form while the anorthosite which is here much crushed and granulated, molded around it. Figure 10 shows a dike in a jagged crevice. Figure 7 is a map of a small dike which appears in the bed of the Branch just above the mill, about a mile or less on the stage road from the Windsor hotel to the Keene valley. It can be followed

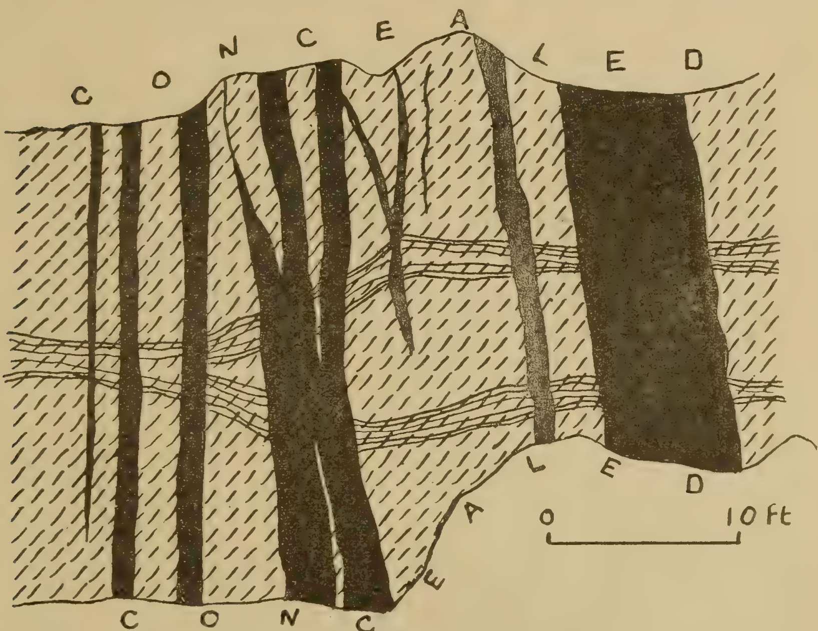

Fig. 11 Network of basaltic dikes in anorthosite and crossing the bed of Slide brook The dikes strike n. 45° w.

in the bed of the cascading brook from one end to the other. Figure 11 illustrates an interlacing network of dikes.

These dikes must have entered the wall rocks under very great pressure, and while in a state almost as fluid as water, must have penetrated every little crevice and crack open to them. They obviously followed the chief structural lines of weakness, and prob-

ably represent the last basic dregs from the great center of eruption which gave rise to the larger masses. In all cases noted they are massive and unmetamorphosed except from weathering. Undoubtedly they followed the great period of metamorphism but shared in some faulting.

Under the microscope the dikes are distinctly basaltic in their mineralogy. Plagioclase and augite are the chief minerals. Olivine occasionally appears, and magnetite is of course in every slide. In the thicker dikes and at the centers of those of moderate width the texture is diabasic; that is, the feldspars are long and narrow and well bounded. They form an interlacing network in whose interstices are the dark silicates. Toward the borders, however, the texture becomes porphyritic with a finer and finer ground mass until at the border the ground mass is a dense, black glass. The dike is cemented at times so tightly to the wall rock, or fused into it, that it breaks more readily elsewhere than along the contact. In several instances where cliffs are exposed along the course of a dike, fragments of the latter may be seen, still adhering tightly to the older walls, although the major part of the dike has disintegrated and disappeared. These relations appear at the dike shown just west of the highway and 2 miles south of Elizabethtown, and also in the one on the northwest corner of New pond.

No analyses have been prepared of the dikes within this area, but a selection is here given of those which have been published from neighboring localities. They will also be found compiled precisely as here given in New York State Museum Bulletin 95, page 350.

	1	2	3	4	5
SiO_2	43.41	44.51	45.46	46.73	50.89
Al_2O_3	19.42	19.99	19.94	16.66	15.39
Fe_2O_3	5.72	7.22	15.36	3.56	5.77
FeO	6.69			8.45	
MgO	5.98	8.11	2.95	8.12	7.60
CaO	9.11	8.15	8.32	8.03	8.75
Na_2O	4.39	5.24	2.12	3.73	5.67

1 Diabase summit of Mt. Marcy, Essex co. A. R. Leeds. N. Y. State Mus. 30th An. Rep't, p. 102.

2 Diabase. Upper Chateaugay lake, Clinton co. A. S. Eakle. Am. Geol. July 1893. p. 35.

3 Diabase. Palmer hill near Ausable Forks, Clinton co. U. S. Geol. Sur. Bul. 107. p. 26.

4 Olivine diabase. Belmont township, Franklin co., dike 13. Analyzed by E. W. Morley for H. P. Cushing. N. Y. State Geol. 18th An. Rep't. p. 120; and 20th An. Rep't, p. 179.

5 Olivine diabase Upper Chateaugay lake, Clinton co. A. S. Eakle, as under no. 2.

	1	2	3	4	5
K_2O	.47	2.60	3.21	1.64	2.72
H_2O	3.00	2.93	2.30	2.39	2.46
TiO_2	.35	....	....	.03	....
P_2O_5	....	....	....	.39	....
Cl	....	....	....	.18	....
F	....	....	....	.26	....
Cr_2O_3	....	....	....	.06	....
MnO	....	....	....	tr.	....
CO_2	2.00	....	....	....	....
BaO	....	....	....	.04	....
	100.54	98.75	99.66	100.27	99.25
O=Cl and F	....	....	....	.14	....
				100.13	

1 Diabase summit of Mt Marcy, Essex co. A. R. Leeds. N. Y. State Mus. 30th An. Rep't, p. 102.

2 Diabase. Upper Chateaugay lake, Clinton co. A. S. Eakle. Am. Geol. July 1893. p. 35.

3 Diabase. Palmer hill near Ausable Forks, Clinton co. U. S. Geol. Sur. Bul. 107. p. 26.

4 Olivine diabase. Belmont township, Franklin co., dike 13. Analyzed by E. W. Morley for H. P. Cushing. N. Y. State Geol. 18th An. Rep't, p. 120; and 20th An. Rep't, p. r79.

5 Olivine diabase. Upper Chateaugay lake, Clinton co. A. S. Eakle, as under no. 2.

	1	4
Or.	2.22	9.45
Ab.	37.21	31.44
An.	15.29	9.73
Calcite	4.50	....
$CaO.Al_2O_3.SiO_2$	13.28	11.34
$CaO.SiO_2$	....	5.34
$2MgO.SiO_2$	10.50	14.34
$2FeO.SiO_2$	5.51	9.69
Ilmenite	.62	....
Magnetite	8.12	5.11
Apatite	....	1.16
Water	3.00	2.39
Etc.	....	.57
	100.25	100.56
Light colored minerals	59.22	50.62
Dark colored minerals	38.02	46.98
Water	3.00	2.39

The recasting was only attempted for nos. 1 and 2 because in these alone was the FeO determined. The difficulty in carrying

it out lies in the assignment of the silica after the orthoclase and albite have been cared for. In order to have enough to combine with the bases, all the magnesia was necessarily assigned to olivine, as was the ferrous iron except what was required for magnetite. The remaining silica was then divided between anorthite and augite. For the latter, the molecule $CaO.Al_2O_3.SiO_2$ was necessarily used with $CaO.SiO_2$. It is probable that this gives too little anorthite and that the magnesia and ferrous iron are not all in the olivine. If so, the necessary silica can only be found by assigning some soda to the pyroxene. There is undoubtedly some kaolin and chlorite, possibly also some serpentine, but there is no means of assigning the water. The proportions of light and dark minerals are doubtless near the truth.

Chapter 5

PALEOZOIC STRATA

Potsdam sandstone. This formation occupies nearly the whole of the Paleozoic fringe about Port Henry. It also constitutes a small fault block at the south end of the Westport area, and it further appears at the north end of the latter in the bed of Hammond brook in Westport village from beneath the Beekmantown beds.

The former extension of the Potsdam formation over all or the greater portion of the Elizabethtown and Port Henry sheets is clearly demonstrated by a small outlier observed by Professor Kemp far back in the mountains. Professor Kemp writes on this exceedingly interesting outlier:

The Potsdam outlier consists of cream-colored or yellowish quartzite, in beds of several inches thick. The strike is n. 20° w., dip 13°e. 12 feet are clearly exposed in one place with no bottom shown, and probably not less than 25 feet are present, perhaps more. The exposure extends 100 yards at least. It lies in the drainage of the Schroon river, down which and 12 or 13 miles to the south is a block of Beekmantown limestone on which is built the village at Schroon Lake post office. This is the nearest of the other Paleozoic exposures.

Another outlier farther north is indicated by the following observations of Professor Kemp:

Again in the area colored for basic anorthosite and 1½ miles northwest of Elizabethtown and near the boundary with Lewis, loose slabs of Potsdam sandstone have been found in such abundance that they have been used for building stone in one or two of the finest residences in Elizabethtown. Careful search along a small affluent of Barton brook revealed many loose pieces, strongly suggesting an outlier in place, but no actual ledge could be located.

The exposures in the neighborhood of Port Henry are by far the most interesting of all, since here the contact with the Precambric rocks, the original surface of deposition of the latter and the basal beds of the Potsdam are shown. The main part of the block is strongly tilted to the east and so deeply eroded in its northern part that the irregular Precambric surface is exposed below the Potsdam sandstone in several places. The best of these exposures is in the southern part of Port Henry where West street crosses a brook. Here the Potsdam sandstone begins at its contact with the Precambric rocks with about 3 feet of conglomerate of arkose character, consisting prevailingly of dark quartz pebbles, smaller grains of fresh feldspar and a yellowish loamy-looking matrix. The quartz pebbles are mostly small and never surpass half an inch in diameter. This is followed by reddish sandstone with irregular conglomeratic bands or streaks, measuring about 20 feet and above this follow about 10 feet of grayish white sandstone with fine grained silicious matrix and many floating, large, rounded quartz grains. This is overlain by the typical white to yellowish Potsdam sandstone. This basal portion is very indistinctly bedded but exhibits clear evidence of current action such as cross striae and plunge structure. Another contact of the Precambric and Potsdam is shown at another inlier along the lower course of McKenzie brook below the highway bridge. Here the bottom layer consists of 3 feet of greenish gray arkose sandstone with scattered pebbles of quartz of the size of cherries, over which beds of fine grained sandstone directly follow. In a third place, also along McKenzie brook, a rather fine grained reddish sandstone, about 20 feet thick, is found to rest in an apparently original depression of the ancient sea floor. A few thin conglomerate streaks near the contact are the only indications of the nearness of the great unconformity. It is thus evident that the coarse basal conglomerate seen in other places had here been worked up by wave action until only a small amount of larger quartz pebbles was left. Nevertheless the wave action was not sufficient to completely plane the sea floor, for the latter is proven to have been very irregular at the time when the basal conglomerate was deposited, by the hummocks of Precambric rocks protruding through the Potsdam sandstone as well as by the presence of original channels in the floor now filled with Potsdam sandstone and exposed in places along McKenzie brook.

The base of the Potsdam formation in this area differs not only from that of others in the slight development of the basal con-

glomerate but also in the absence of the deep red, hematitic arkose sandstones so abundant in the basal portion of the Potsdam in Clinton county and on the north border of the Adirondacks. Altogether the sandstone of this area resembles in its physical characters more the middle and upper divisions of the Potsdam as distinguished in the typical sections at Keeseville and Potsdam by Van Ingen and Cushing, than it does the lower portion. It is best exposed at Port Henry in Bond's quarry above the Mineville railroad track and in the cut of the Delaware and Hudson Railroad north of the station. In the former place, as also along the upper McKenzie brook, white and yellowish fine grained, partly heavy bedded and partly slabby sandstones with occasional shaly bands prevail. By universal cross bedding, floating large sand grains, ripple-marked surfaces (beautifully displayed along McKenzie brook) and intercalations of brecciated beds it is indicated that these sandstones which would seem to correspond to the middle portion of the Potsdam[1] were deposited not far from the shore line. In the railroad cut about 60 feet of whitish gray sandstone in one-foot courses are exposed that present the typical and usual appearance of the Potsdam sandstone. These beds are within a third of a mile of the exposure of the Beekmantown beds at the tunnel and since they dip in that direction, the interval of drift-filled valley is inferred to be eroded in the remainder of the Potsdam series.

The isolated exposure of Potsdam beds in the fault block at the south end of the Westport Paleozoic area is again composed of evenly bedded brownish, yellow and white sandstones corresponding to the higher portions of the formation. About 100 feet of these are exposed in the railroad cut. The third exposure of Potsdam sandstone in the portion of the quadrangle here discussed is in the village of Westport above the highway bridge and along the shore. Only about 35 feet, consisting of whitish sandstone in one-foot beds followed farther up by heavier beds of brown sandstone, are exposed.

While the evidence on the development of the Potsdam formation in the area under discussion, owing to its faulted and much eroded condition is very incomplete and time was lacking for a more exhaustive investigation of the formation, it seems fairly certain that the lower Potsdam, and probably also the upper Pots-

[1] The reported finding of a small trilobite, probably Ptychoparia minuta, on upper McKenzie brook, may also indicate, however, the presence of beds equivalent to a part of the upper 350 feet of the Ausable Chasm section, i. e. of upper Potsdam beds.

dam beds, are here not as fully developed as in Clinton county and that the formation as a whole does not attain the great thickness it has farther north.

Beekmantown formation. The Beekmantown formation has been found during this investigation to be well exposed along the shore from Cold Spring bay to Cole bay, in the Westport area. The section begins with the division A of the Beekmantown at Cold Spring bay, south of Westport, the transition beds to the Potsdam farther north being hidden from view by drift. Owing to the west to south dip of the beds the other divisions are successively brought up in the shore cliffs and their characteristics can be studied in detail. Care must, however, be taken since low anticlines and faults have caused repetition of beds and the disappearance of portions of the section, especially in D which therefore is incompletely exposed.

The greater part of divisions A and B is probably covered, but division C which occupies the lake shore from the promontory east of Cold Spring bay past Barber point to the point east of Cole island is splendidly exposed in all its subdivisions; the only important disturbance appearing at Young bay where probably a minor fault passes out and south of Barber point where a low anticline causes a repetition of the beds. Of especial interest are beds of coarse breccias in C_2, containing angular blocks of the preceding divisions, some 2 feet in diameter. These brecciated beds are repeated several times. C_3 which is exposed at Barber point, is a sandstone much resembling the Potsdam sandstone and covered on the surface with great numbers of spirally curved worm casts. Below the light-house C_4, the magnesian limestone no. 2 is exposed. This also is brecciated and is followed again by the worm-tube marked sandstones of C_3 which extend for half a mile south of Barber point and are followed by the magnesian limestones of C_4 which here, as in the Shoreham section of Vermont,

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[1] We have here adopted the subdivision of the Beekmantown (Calciferous) formation in five members (A, B, C, D and E), first proposed by Brainerd and Seely [Am. Mus. Nat. Hist. Bul. 3:1, p. 2–3; *see also* Cushing. N. Y. State Mus. Bul. 95, p. 361]. Division A consists in Brainerd and Seely's type section at Shoreham in Vermont of 310 feet of dark iron-gray magnesian limestone, that in some beds approaches a sandstone; division B of 295 feet of dove-colored limestone; division C (350 feet) of magnesian limestone and sandstone; division D (375 feet) of blue and drab limestone and sandy limestone; and division E (470 feet) of fine grained magnesian limestone with thin layers of slate near the top.

are characterized by patches of black chert, square yards in size. At the point northeast of Cole island the beds of division D begin with bluish gray massive limestones, weathering with irregular surface owing to the dolomite content. This subdivision D contains also many indistinct sections of Ophileta. The section continues westward to Cole bay, at the northern boundary of which, opposite Cole island D_4 characterized by thin, tough, slaty layers of limestones is shown. Back of Cole bay in the falls of Stacy brook over 100 feet of division E are finely exposed. They appear as drab to bluish gray magnesian limestones, regularly divided into one-foot beds with shaly intercalations. The upper beds abound in crinoid joints; otherwise fossils seem to be rare in this locality.

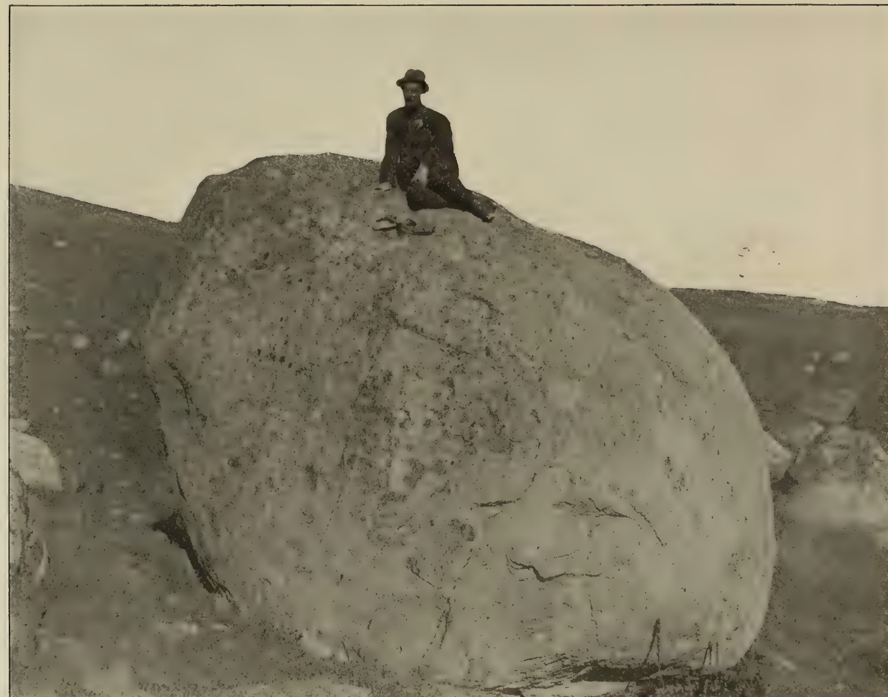
South of Cole bay the contact of the Beekmantown and the Chazy can be followed for a long distance. Since here this contact, which is rarely seen, is well exposed, we will insert the details of the section, which have been studied in company with Dr E. O. Ulrich:

10′	Conglomerate, heavy bedded, crystalline, bluish black limestone (Chazy) with Phylloporina incepta, grading upward into the banded limestone with Maclurites. At the base are irregular crystalline 6′ layers, full of fossils: Phylloporina incepta and numerous ostracods, small and larger trilobites, fragments of Orthis costalis and other brachiopods. Most of the beds (lower half) more or less conglomeratic. Base of Chazy
2′	Even blue, calcareous shale. No fossils
2′ 6″	Fine grained, earthy, mottled, light and darker gray bluish impure limestone
2′ 6″	Thin, light bluish shale with thin earthy and sandy limestone intercalations. Full of small branching fucoids
8′	Black, whitish weathering, blocky, impure, barren, bluish gray dark limestone with shale partings. Lighter colored, finely granular to every compact, limestone in layers of 3 inches to 2 feet

It will be seen by this section that the lithologic change from the Beekmantown to the Chazy is abrupt. Since the Chazy begins with conglomeratic beds, there is little doubt of an unconformity at its base.

Another smaller series of outcrops has been observed in the Westport area on the other side of the plain of Champlain clays near the foot of the line of bluffs of Precambric rocks marking the

Plate 12

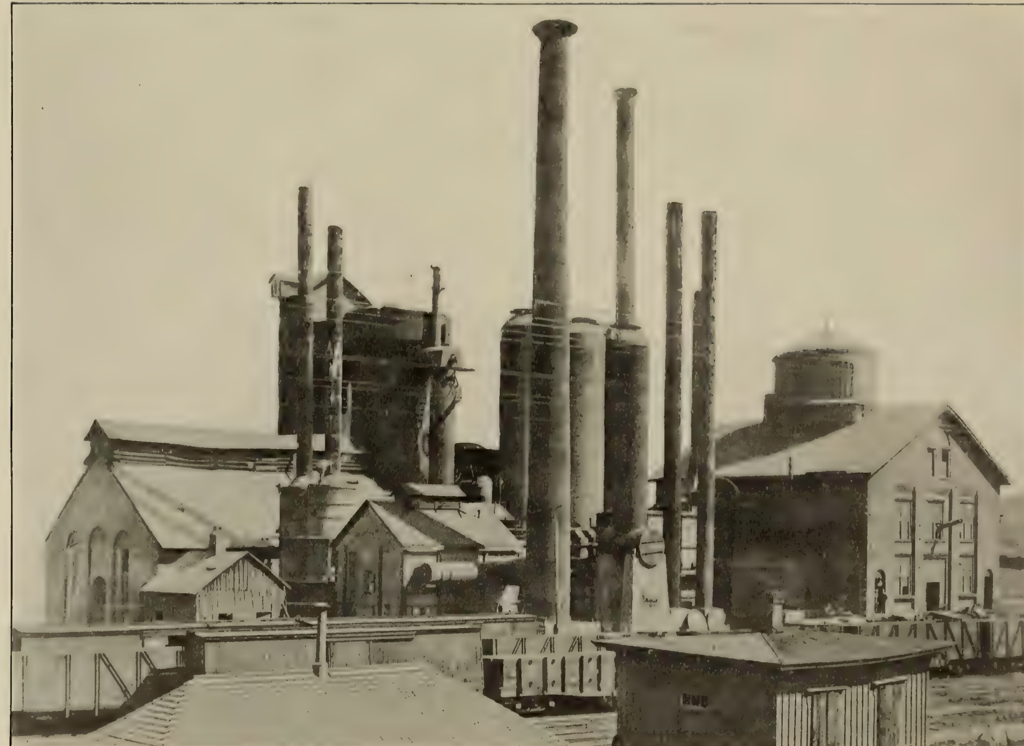


Glacial boulder, 12 feet in diameter; pear-shaped. Barton hill, Mineville

Plate 13

Colburn furnace, a charcoal stack built in 1848, about 1 mile west of Moriah Center, near Mineville

Plate 14



The Cedar Point furnace of the Northern Iron Co. Port Henry, 1908

Plate 15

Mine "21," Mineville, N Y. looking nearly east

Plate 16

Mine "21," Mineville, N. Y. looking southwest into the Tefft shaft chamber. Mt Tom is in the background.

direction of the master fault of the region. The most important of these are found along the highway leading along the base of the fault scarp near the upper stretches of Beaver brook and along its branches.

The Port Henry area of Paleozoic rocks contains at its north end a most interesting exposure of Beekmantown rocks at both ends of the railroad tunnel and especially along the shore to the east of the tunnel and north of the same as far as Craig harbor. About 80 feet of division A are exposed in the cliff through which the tunnel has been driven. These, mostly the dark iron-gray dolomites, characteristic of the division, exhibit heavy beds at the base, that consist of rounded quartz grains cemented by a dolomitic matrix and representing the basal beds of the formation or at least indicating closeness to its base. The beds are frequently cross-bedded, some show very irregular surfaces and bedding planes and others display an irregularly nodular structure, while the beds resting on irregular surfaces contain pebbles of the underlying courses. The beds of this subdivision bear here evidence of much disturbed disposition, although much of the brecciated appearance is undoubtedly due to later crushing of the beds [*see* below p. 91]. In the railroad cut to the north of the tunnel the upper beds of division A, marked by black chert bands, are seen, and beyond a depression follow the purer limestones of division B which extend as far as Craig harbor and are here quarried extensively to be used for flux on account of their relative purity. This outcrop complements to a large extent that of the Westport area, exhibiting the lower beds which there are only partly exposed. Neither of the divisions showed any traces of fossils save fragments of linguloids observed by Kemp and Matthew in the arenaceous basal beds in the railroad tunnel, and the much disturbed condition of the beds did not allow of reliable measurements of their thickness.

The third appearance of Beekmantown beds on the sheet on this side of the lake is that on Crown Point peninsula. Here only three outcrops could be found, one on the shore of Bulwagga bay, another near the road and a third in the middle of the east shore. The first, as originally described by Brainerd and Seely and more fully elaborated by Raymond, contains but the barren top layers of the Beekmantown, while the others are fossiliferous outcrops of the divisions D and E.

In the first two outcrops only a few feet of a light-gray dolomite are shown which are directly followed by the basal beds of the

Chazy. The other outcrop comprises 150 feet in one continuous section and amounts altogether to about 300 feet of rock, consisting mostly of steel-gray to bluish gray compact dolomitic limestone with rough surfaces on the weathered beds, suggesting D_1, and sandy limestone in thin beds weathering on the edges in horizontal ridges and denoting D_3. Indistinct sections of gastropods were observed in several beds.

Although it would seem desirable to map separately the divisions of a formation aggregating 1800 feet in thickness, the scattered position of most outcrops and the obvious presence of numerous tectonic disturbances, indicated by the varying dips, would not have allowed anything approaching correctness in the drawing of the boundaries. Only on the east side of the Westport area, along the lake shore the boundaries of the divisions could be drawn in and continued according to the prevailing north northwest strike in this region for some distance. But the western continuations of these boundaries are entirely lost under the Champlain clays and the accompanying description will suffice to locate the divisions along the shore. We have also refrained from separating as a distinct unit on our maps the Cassin formation from the rest of the Beekmantown, although its recognition as a distinct unit is urged by Professor Cushing, apparently on good grounds. This Cassin formation is to comprise the upper portion of D and all of E. In the areas here under discussion it is exposed around Cole bay, between the highroad and the fault scarp near the northern branches of Beaver brook, and it also is represented in the outcrops on Crown Point peninsula.

It is also probable that the division A, amounting to over 300 feet of rock, will in time be separated from the Beekmantown by Dr Ulrich who considers it the eastern representative of a separate formation having possibly even the value of a system that is fully developed in the Mississippi basin. At any rate, there is good evidence that a strong unconformity separates division A from the rest of the Beekmantown. The rocks of A are best exposed in the cliff north of Port Henry through which the tunnel passes. Less favorable exposures are found at Cold Spring bay and near the base of the fault scarp in the Westport area. The northernmost of these exposures is a small abandoned quarry ½ mile north of Westport and ¼ mile east of the railroad track.

Chazy formation. The Chazy is exposed in complete sections in two places, viz, in the Westport area where the section extends

from the contact with the Beekmantown beds, south of Cole bay, along the shore to Mullen bay, and on Crown Point peninsula. Scattered outcrops occur also in the Westport area along the highway. The section of Crown point has been first described by President Brainerd[1] who found a thickness of 305 feet and believed he recognized all three of the Chazy divisions, distinguished in the type section. He gives the following section in ascending order:

			FEET
A	1	Sandstone and slate interstratified..................	23
	2	Impure limestone containing Orthis platys..	25
B		Beds containing Maclurites magnus.......	200
C	1	Dark gray massive limestone, weathering in dark stripes an inch wide, containing Bucania sp. und.	40
	2	Tough, silicious and magnesian rock, passing into a two-foot bed of pure sandstone..............	17
		Aggregate thickness......................	305

This section was later on most carefully investigated by Dr Raymond[2] who, by means of the fossil evidence, concluded that only the middle division B (which he terms the Maclurites magnus division) is present, the Chazy sea reaching so far south only during the hight of the invasion in middle Chazy time. In a later publication[3] the following summary of his investigation of the Crown Point section is given:

A_{1-2}. Thick beds of slaty shale with occasional bands of hard, fine grained sandstone. Fucoids numerous.

25 feet 2 inches=25 feet 2 inches

Lingula brainerdi, a

A_{3-8}, C_1. Impure blue limestone, rather thin bedded.

91 feet 10 inches=117 feet

Plaesiomys platys, c	Camarella longirostris, r
Hebertella vulgaris, c	C. varians, r
Rafinesquina alternata, c	Maclurites magnus, r
R. incrassata, c	Isotelus harrisi, c
Zygospira acutirostris, r	Leperditia canadensis, c
Orthidium lamellosum, r	L. limatula, r
Lingula *sp.*, r	Eurychilina latimarginata, r

Concealed 34 feet=151 feet

[1] Geol. Soc. Am. Bul. 1891. 2:300.

[2] Am. Pal. Bul. 14. 1902.

[3] Carnegie Mus. Ann. 1906. v. 3, no. 4, p. 551.

B_{1-4}. Impure, thin bedded fine grained limestone.
16 feet 6 inches = 167 feet 6 inches

Plaesiomys platys, c	Bucania sulcatina, c
Rafinesquina alternata, r	Maclurites magnus, r
R. champlainensis, c	Ctenodonta peracuta, rr
R. incrassata, rr	Isotelus harrisi, r
Camarella varians, rr	Thaleops arctura,[1] rr
Raphistoma stamineum, r	Leperditia limatula, c
R. striatum, rr	

Concealed 31 feet = 198 feet 6 inches

B_{6-16}, C_{3-12}. Impure, rather shaly limestone interstratified with heavy bedded, fine grained blue limestone.
80 feet = 278 feet 6 inches

Palaeocystites tenuiradiatus, c	Raphistoma stamineum, c
Monotrypella *sp.*, r	Bulcania sulcatina, c
Rhinidictya fenestrata, rr	B. bidorsata ?, c
Plaesiomys platys, c	Lophospira perangulata, r
Rafinesquina alternata, c	L. *sp. ind.*, r
R. champlainensis, c	Maclurites magnus, c
R. incrassata	Orthoceras *sp. ind.*, r
Camarella longirostris, r	Plectoceras *sp. ind.*, r
C. varians	Bathyurellus minor, r
Ctenodonta peracuta, rr	Isotelus harrisi, c
C. dubiaformis, rr	I. obtusus, r
Clionychia montrealensis, r	Thaleops arctura, r
Archinacella ? deformata, r	Pliomerops canadensis, rr
A. ? propria, r	Leperditia canadensis, c
Eccyliopterus fredericus, r	L. limatula, c
E. proclivis, r	Eurychilina latimarginata, r
Raphistoma striatum, r	

C_{13-14}. Very hard, blue gray magnesian limestone, weathering so as to show alternating light and dark stripes about an inch wide.
24 feet 6 inches = 303 feet

C_{15}. One layer of coarse grained sandstone in which there are many cavities, as though fossils had been dissolved out.
2 feet = 305 feet

C_{16}. Hard, magnesian limestone containing many large waterworn sand grains. 1 foot = 306 feet

Plaesiomys platys, r	Raphistoma stamineum, r
Camarella varians, r	Isotelus harrisi, c

[1] Dr Raymond cites this form as Thaleops ovata, since at the time he considered Hall's Illaenus arcturus as a synonym of Thaleops ovata Conrad. He has, however, later [Ann. Carnegie Mus. v. 4, no. 3. 1908, p. 248] separated again the Chazy and the Trenton forms, referring Illaenus arcturus also to Thaleops.

It is added that the section like that of Valcour island begins with a basal zone with Lingula brainerdi which, however, is not considered as representing "one horizon holding a definite place in the time scale, but as a tangential sandstone marking the base of the invading sea" and that the fauna is chiefly a brachiopod one, characterized by Rafinesquina champlainensis, Rafinesquina incrassata, Plaesiomys platys, Camarella varians, Raphistoma stamineum, Maclurites magnus, Isotelus harrisi, Thaleops arctura and Leperditia limatula. Four of these, viz, Rafinesquina champlainensis, Plaesiomys platys, Maclurites magnus and Leperditia limatula are cited as characteristic of the second or Maclurites magnus fauna at Valcour island.

The base of the Chazy is exposed at the east shore of Bulwagga bay where a few feet of the subjacent Beekmantown formation are seen. The Maclurites are observed here to come in directly above the basal 25 feet of slates and sandstone. Only about 50 feet are exposed along this shore in continuous section. The middle and higher beds are excellently shown along the shore, west of the light-house and in the pastures back of the shore. The last 26 feet which are best exposed west of and within the fort are peculiar in several respects. Most striking among these and all Chazy beds in this section are the white and black banded limestones (C_{13-14}), the bands, which appear on weathering, exhibiting in many layers fine examples of brecciation and recementation of the broken fragments, also oblique striation and plunge structure and other evidences of deposition in turbulent waters.

The Chazy is brought up again by a fault close to the southern boundary of the sheet. It is also here characterized by its fauna, notably numerous specimens of Maclurites magnus, as belonging to the middle division.

The section in the Westport area is not so easily accessible since, for the most part, the rocks are only exposed in a vertical cliff along the shore. Several outcrops appear also farther inland, along Beaver brook and the highway. Near the top several beds are found that either are not exposed or absent in the Crown Point section. One of these consists of unfossiliferous heavy bedded limestone with a basal bed of crinoidal limestone containing numerous large sand grains and composed in places nearly entirely of a small apparently new Camarotoechia. The base of the formation is well exposed, resting on the Beekmantown, south of Cole

bay; and likewise the top in a bed of magnesian limestone with many streaks of sand grains and few fossils. Five feet of this limestone are exposed in the point bounding Mullen bay on the east.

Black River group.[1] The Chazy is followed in the Crown Point section by 5 feet of dove-colored limestone which in part strikingly resembles the "Birdseye" or Lowville limestone to the south and west of the Adirondack plateau and also contains the characteristic vertical worm tubes (Phytopsis tubulosus Hall). This bed which is exposed outside the fort at the north entrance has been considered as representing the Lowville formation in the Champlain basin. Since, however, the writer found 15 feet above its top, in a bed of the "Black River formation," numerous typical specimens of Tetradium cellulosum[2] which in the Black River and Mohawk regions is the most characteristic fossil of the Lowville limestone, and as far as we know is there restricted to it, it is possible that the 5 feet of dove-colored limestone represent only a part of the Lowville formation and that a portion or all of the "Black River" of this section is equivalent to the Lowville. Indeed, it is claimed by Dr Ulrich that all of the "Black River" limestone of the Champlain valley is older than the Watertown limestone and is to be correlated with the Lowville formation. In the Westport area the dove-colored limestone has not been found.

A careful section of the "Black River" of Crown Point peninsula with fossil lists is given by Dr Raymond in the before cited paper. Two zones are distinguished, one, 7 feet of lumpy, black and heavy bedded limestone with a pelecypod fauna, and a second, 55 feet of lighter colored rock containing a brachiopod and crustacean fauna. The lower 24 feet of the latter portion are coarse grained while the remainder is fine grained. The lowest 15 feet of these beds in this section were found by us to contain chert in numerous nodules and even in continuous layers and the inference itself suggests that this "Black River" corresponds to the cherty limestone or the Leroy member of the Lowville formation.

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[1] The Black River group, as now understood by this survey, comprises the Lowville limestone, the Watertown limestone (formerly the Black River limestone) and the Amsterdam limestone).

[2] Not listed by Raymond. There occur also in this horizon Hormoceras tenuifilum, Lituites and Oncoceras sp.; also not listed in the previous publications.

As the most characteristic fossils of the Black River group in this locality are cited by Raymond:

Maclurites logani *Salter*	Zygospira recurvirostris *Hall*
Plectorthis plicatella *Hall*	Stromatocerium rugosum *Hall*
Strophomena incurvata *Shepard*	Columnaria alveolata *Goldfuss*[1]
Leperditia fabulites *Conrad*	

We have also observed some of the cephalopods so characteristic of the Black River beds at Watertown, notably Hormoceras tenuifilum and Plectoceras sp. (probably undatus). They were associated with Tetradium cellulosum and Orthoceras rectiannulatum, two typical Lowville fossils at Watertown but they appear also in the Watertown region already in the Lowville beds.

The lithologic characters of the Black River rocks at Crown point and in the Westport area are for the most part strikingly like those of the Watertown limestone at Watertown, in the fineness of the grain, the dark color and fine veining as well as the peculiar small blocky weathering.

In the Westport area the belt of Black River limestone begins at Mullen bay as indicated by a big angular boulder that has obviously been transported but a short distance and contains a large colony of Columnaria ?halli.[1] The belt strikes thence north-northwestward in the direction of Beaver creek and is exposed in two places in the creek bed, at one of which large specimens of Maclurites logani and of Stromatocerium can be seen.

Trenton limestone. Only the lower portion of the Trenton limestone is exposed in either the Westport area or Crown Point peninsula and this consists in both localities of thin bedded, slabby, mostly impure, very fossiliferous limestone with shaly partings. On the Crown Point peninsula there are 88 feet exposed, the remainder of the formation, which on the opposite shore in Vermont attains 314 feet, being hidden under the waters of Bulwagga bay. Raymond has distinguished several fossil zones in the Trenton, the lowest one of which is that of Raphistoma lenticulare comprising 4 feet 9 inches, separated from the Black River by a covered interval of 4 feet. It is followed by the Parastrophia

[1] As pointed out by Nicholson [Palaeozoic Tabulate Corals, 1879, p. 200], Winchell and Schuchert [Geol. Minnesota, v. 3, pt 1, 1895, p. 85], the Columnaria alveolata of American authors is not identical with Goldfuss's species and should be known as Columnaria ? halli Nicholson.

hemiplicata zone of T. G. White, (20 feet 9 inches), and this in turn is overlain by beds characterized by Trinucleus concentricus (about 20 feet) and the last 7 feet contain abundant fragments of Asaphus platycephalus.

South of Mullen bay in the Westport area, Trenton beds containing Parastrophia hemiplicata come up for a short distance along the lake shore, and the shingle farther south as far as the Potsdam outcrop is also nearly entirely composed of Trenton limestone slabs.

About 40 feet above Mullen bay in the railroad cut and along the road other small outcrops and masses of Trenton boulders are found. Some of these indicate the presence of the zone of Trinucleus concentricus. Finally the Trenton reappears again close to the fault scarp of the Precambric below the mill dam on Mullen creek with an outcrop of about 40 feet of impure limestones and alternating shales, the former containing the common brachiopods and Calymmene senaria, the latter a Diplograptus of the amplexicaulis type.

Trachyte dike. On the northern side of Cole bay, in Westport, there is an east and west dike of the trachytic rock, to which the special name of bostonite was given years ago. It cuts the Beekmantown limestone, but inasmuch as the same kind of igneous rock is elsewhere found penetrating the Utica slate, it undoubtedly marks a post-Ordovicic outbreak. Full details of these and associated eruptives will be found in the citation below.[1] The dike at Cole bay is a pale, gray felsitic rock, when unweathered, but is dark brown on the exposed surfaces. In thin section it presents a mass of tiny feldspar crystals, apparently orthoclase. The structure is strongly trachytic; that is, the little rods are interlaced and more or less parallel, with occasional flowing arrangement. No dark silicates remain, but a few rusty decomposition products suggest their former presence but in very small amount. No special analysis has been made, but those which have been prepared from other dikes lead us to believe that the silica is in the neighborhood of 60 per cent; the alumina 20; the potash and soda about 5 each; while the other components make up the balance. This dike is the most southerly of the bostonites thus far discovered. These peculiar dikes are rare types of eruptives and possess much petrographic interest.

[1] Kemp, J. F. & Marsters, V. F. The Dikes of the Champlain Valley. U. S. Geol. Sur. Bul. 107.

Chapter 6

STRUCTURAL GEOLOGY

Faults

Faults are of more than usual importance in the Adirondacks and the Champlain valley. They have been frequently and necessarily referred to in the opening description of the general relief. While the discordance produced by these displacements can not always and can not easily be demonstrated in the ancient crystallines, yet the tilted block character of the topography, the frequency of precipitous escarpments, the innumerable cross gulches along the crests of the ridges and the crushed and sheeted rock revealed by cascades in the brooks, all leave no alternative to the observer other than to believe in the general presence of these dislocations. There are, however, some positive forms of evidence which are more tangible, and it will be the purpose here to pass them in review.

Faults in the Paleozoic strata. Dislocations in the Paleozoic rocks have long been known and outside the present area are exhibited with diagrammatic clearness. They have been matters of record since the early work of Ebenezer Emmons, and in Chazy township, north of Plattsburg have been mapped and studied by Professor Cushing.[1] Near Port Henry and Westport they are not so clearly exhibited between individual members of the Paleozoic as they are farther north, but as between the Paleozoics and the older crystallines, they are well known.

The clearest case is afforded by the block of Beekmantown limestone, just north of Port Henry. As one passes through the two tunnels and across a small inlet, a block of this silicious, magnesian limestone is encountered which rises 100 feet or more above the lake. It is extensively quarried for flux for the Port Henry blast furnace and also for macadam. It has a very flat dip of 10 northeast and a strike of n. 55° w. If projected across the little embayment called Craig harbor on the map, it would abut abruptly against the Grenville. There is obviously a fault which causes the discordance and which passes northeast and southwest. The sheeting and crushing of the rock have given rise to the embayment, which has been worked back by the waves through the broken rock.

Another significant feature is found in the prevailing dips of the Potsdam and later strata. They are almost or quite always in-

[1] Cushing, H. P. Faults of Chazy Township, Clinton County, N. Y. Geol. Soc. Am. Bul. 1895. 6:285.

clined at low angles downward toward the next exposure of the Precambric, whereas if they were resting upon the latter in a depositional relation, they ought to slope upward to them. If, however, dropped by faulting, they would readily assume the relations observed.

Faults in the Precambric rocks. Faults are sometimes shown by the brecciated condition of the ancient crystallines. Figure 12 is a sketch to scale of an exposure of anorthosite south of the road, and near the Woolen mill, a mile or less west of Elizabethtown, where the exposures shown in figure 7, page 41, were mapped. The star upon this last named figure shows the exact spot. The

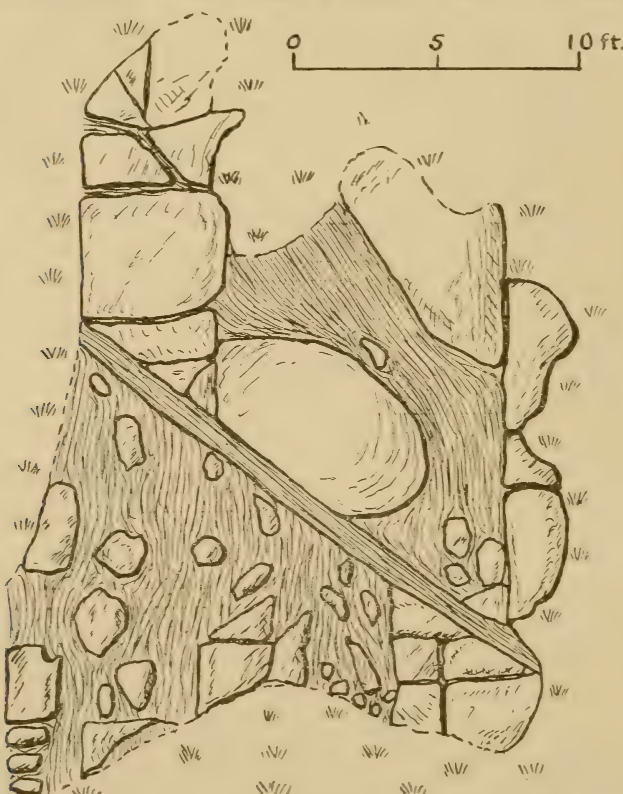

Fig. 12 Faulted and crushed anorthosite near Woolen Mill 1 mile west of Elizabethtown. The exact locality is shown by a star in the lower part of figure 7.

anorthosite has been crushed to a blocky breccia whose larger pieces are embedded in a sheared and schistose matrix derived from the comminuted particles. Besides the general crush, it would appear as if the upper portion of the diagram had been moved northwest

about the width shown, making the marked secondary sheared band which crosses it. The broken blocks in the lower right-hand and upper left-hand corners appear to correspond fairly well.

Brecciated exposures such as this have been met from time to time elsewhere. A quarter of a mile north of Cheever dock on Lake Champlain, and in granitic gneiss of the syenite series, there is another one beautifully exposed in the cuts of the railway. The fault has broken the brittle gneiss to a mass of angular bits, of which the individuals range up to 2 or 3 inches across and are cemented by finely crushed and chloritized material. In these brecciated exposures it is not always easy to detect the exact line of movement, since the result is chiefly the brecciation, but the attendant sheeting in the case just cited runs northeast.

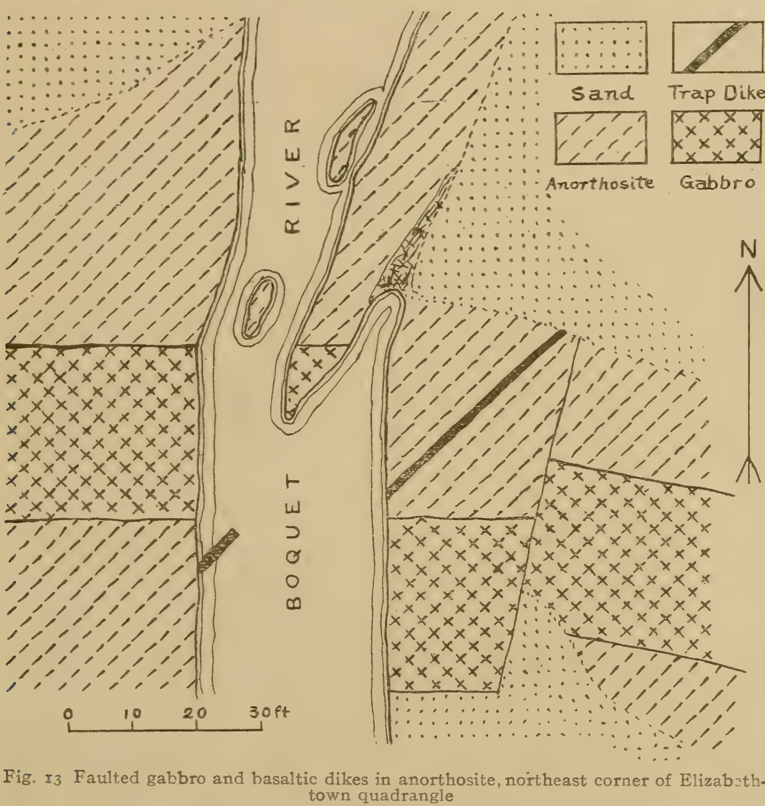

Fig. 13 Faulted gabbro and basaltic dikes in anorthosite, northeast corner of Elizabethtown quadrangle

Occasionally a fortunate combination of contrasted formations and faulting gives a clue to the nature and amount of the displacement. One such case is to be seen in the bed of the Boquet river

where the highway crosses it by a ford in a northeasterly direction and in the extreme northeast corner of the Elizabethtown quadrangle. This is illustrated in figure 13. The country rock is anorthosite which has been cut by an east and west gabbro dike, 27 feet wide. Still later but before the faulting a narrow black trap dike penetrated both rocks with a northeast strike. The complex was then dislocated by two faults of which the westerly one moved the two dikes to the south about the width of the gabbro, and the more easterly moved the eastern prolongation about 10 feet back to the north. The figure gives the actual exposures, and where no rock symbol appears they are beneath the stream gravels. The trap dike appeared to terminate against the western bank, but no appreciable faulting was evident.

Figure 14 illustrates all that can be seen of a horizontal band of black hornblendic rock in the white Grenville marble, a hundred yards north of Cheever dock. This is believed to be a dike or narrow sheet, which, 6 feet in width, penetrated the limestone. It has been so broken that only three blocks remain visible and two of these are separated by 60 feet of an interval. The limestone has molded itself into the interval, obviously while plastic under pressure, illustrating those flowage phenomena which led Professor Ebenezer Emmons to consider the limestone an igneous rock.[1]

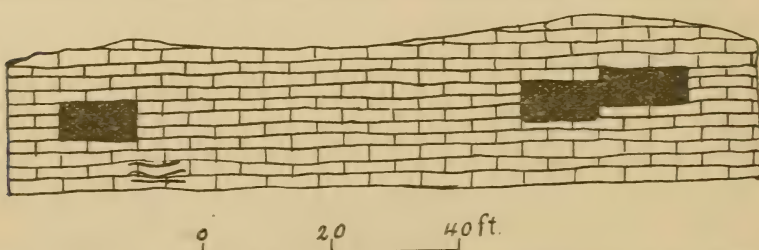

Fig. 14 Faulted blocks of black hornblende schist, presumably intrusive and now in Grenville limestone, just north of Cheever dock, Port Henry

Much the same thing is shown in plate 11 from a photograph in the limestone quarry south of the Pilfershire mines and just east of Barton brook. A sheet similar to the last has been broken into three pieces, of which the middle one has been pushed upward by the viscous limestone.

In the mines we find the best cases of faulting and the ones most clearly shown. Fortunately while the Cheever mine was being

[1] Geology of the Second District. N. Y. State Nat. Hist. Sur. 1842. p. 37.

operated in 1880, it was visited by Bayard T. Putnam as agent for the Tenth Census. Putnam was a most careful observer, who combined the keen sight of the geologist with the habits of record of the engineer. He plotted a cross section of the Cheever ore shoot, which shows it to be broken by nine little faults, all normal ones, although dipping first in one direction and then in another. They ranged from 28 to 78 feet apart and revealed displacements varying from 1.5 to 31.1 feet.[1] Some years after Putnam's visit the workings encountered a much larger fault which is stated to have cut off the ore.

In the large mines at Mineville not only are faults indicated by the relations of the ore, but at the western side of the Old Bed pit, the crushed and decomposed rock and slickensided faces can be seen over a width of about a foot. In the subsequent descriptions of the ore bodies these features will be again referred to.

The accurate and instructive exhibitions of faults which the mines reveal may with justice lead to the inference or at least the suspicion that faults are far more abundant than we have supposed, rather than that they are fewer. At all events increasing experience inclines us to a greater and greater faith in their existence. One is even justified in regarding each topographical depression as not only the possible but the probable location of one. The only other probable line of weakness in the Precambric areas is a bed of limestone.

Chapter 7

AREAL DISTRIBUTION OF THE SEVERAL FORMATIONS

Introduction. The delimitation of the areal geology involves great difficulties. The region has been heavily glaciated and in the higher altitudes drift is very abundant and serves to conceal the outcrops. Along Lake Champlain in the Paleozoic areas the Champlain clays mantle the surface and afford comparatively few ledges. The more mountainous districts are forested, and have been at least once and often several times cut over. The younger growth is thick and difficult to traverse. One might pass a ledge at a short distance without detecting it. But the most unsatisfactory features of all are involved in the nature of the ancient crystallines themselves. In the preceding descriptive pages their characteristic features have been set forth in as definite a way as possible in

[1] Tenth Census. 1885. 15:112–14. The 31.1 feet may be a misprint for 3.1 since Putnam states specifically that 13.5 is the greatest displacement observed.

order to establish reasonably sharp conceptions. In typical exposures all these are exhibited with all desirable clearness. Thus there is never any doubt about the crystalline limestones of the Grenville; and the associated schistose rocks, quartzites, and thinly foliated, rusty gneisses are almost equally easy to identify. Repeatedly some little exposure of the last named has attracted attention and has led to the later discovery of anticipated limestones. But as more massive gneisses are met the difficulties of drawing the lines of demarcation increase. No geologist can escape great uncertainty of mind in these regards. The writer has endeavored to set some of these fully and frankly forth in the subsequent discussion of the stratigraphic relations of the iron ores, and in the details of the Port Henry area of the Grenville. From long residence upon the metamorphosed sediments represented by the mica schists of Manhattan Island and familiarity thus acquired with undoubted rocks of this type on the one hand, as well as study of the Adirondacks and Highlands, as representatives of intrusive types, on the other, a disposition has been acquired to look for decided and fairly regular schistosity as an indication of sedimentary origin and in questionable cases, seeing that we are dealing with an undoubted plutonic district, the irresistible tendency is to place the massive gneisses of composition corresponding with intrusives, in the category of the eruptive rocks. Upon the map therefore in not a few cases the heavy massive gneisses have been put with the syenite series, with which also their mineralogy allies them, and with whose typical representations they are connected by imperceptible gradations. Yet it is quite conceivable that another observer might reach a quite different conclusion.

Another very troublesome difficulty arises in this further particular. From the typical representatives of the anorthosite, syenite and gabbro series, there are variations. Anorthosites in characteristic exposure contain little else than labradorite or some related plagioclase, and of this type there is no lack. But dark silicates appear in greater and greater amount; orthoclase does not entirely fail; and gneissoid structures are produced by the omnipresent crushing and shearing. In the end gneisses result, largely dark silicates, yet with augen or knots of blue labradorite still distinctly visible. Thus the Split Rock and Woolen Mill types result, both of which are intrusive in anorthosite. Yet the intermediate stages are well developed, especially along the outer border of the anorthosite mass and after much uncertainty as to the best course it was decided to color the basic anorthositic border as has

been done by Professor Cushing in the Long Lake sheet, and submit in the text the details of such intrusive relations as had been detected.

Again, if we start with the typical syenites of which there are good representatives, we find variations both toward the acidic and the basic extremes. Full details with analyses of these are given in the pages discussing the syenite series and under the ore bodies of Mineville, where the diamond drill has afforded exceptional facilities for study. The basic phases when sheared into gneisses afford rocks almost if not quite indistinguishable to the eye, from the basic phases of the anorthosites. Thin sections can not be prepared nor can microscopic determinations be made of every exposure. Indeed their importance and help can be easily overrated. Much uncertainty has been unavoidably felt. The writer can only state that after repeated study, he has chosen the coloring to the best of his ability. The acidic extreme on the other hand approaches both the granitic series and the possibilities of metamorphosed sediments.

Finally the basic gabbros have not escaped the general shearing and visibly pass into gneissoid phases in excellent exposures. They imitate almost if not quite indistinguishably basic phases of both syenites and anorthosites and contribute to the difficulties not alone of drawing boundaries, but of identification itself. Starting out from a typical and easily recognized exposure of massive gabbros, one may pass over dark gneisses, and hybrid types almost without limit, before another sharply identifiable ledge is met.

The lack of sharpness of characters has led the writer to look somewhat favorably upon the possibilities of infusion among the deep seated rocks. That is, a great plutonic mass may have absorbed into its border portions of so much of the older wall rock as to give an intermediate result neither one thing nor the other. While perhaps a difficult process to demonstrate, it nevertheless has its attractions and its reasonable side. If, for instance, anorthosites grow more basic at the borders, and if we have only fragments of an old limestone bearing Grenville series left, like islands at times in its midst, what more natural than that by absorption the bases of the old anorthosite magma have been increased to the point where pyroxenes and hornblendes become inevitable. An original magma, heated well above the bare requirements of fusion would, of course, be necessary to bring about this process, but there seems no insuperable objection to it at the heart of a great igneous center.

These introductory points having been stated, the areal geology may be passed briefly in review and notes may be recorded upon the more interesting features of each.

Distribution of the Grenville. The most extensive single area of the Grenville begins in the northern outskirts of Port Henry, and extends northward to and beyond the Cheever mine. The limestones are comparatively thick and are well exposed both by the railway cuts along the lake shore and in the quarries which have been opened for stock for the furnaces. North of Craig harbor and again north of Cheever dock the continuity is broken by intrusive masses of the syenite series which tongue into the limestone and which have probably contributed to its extreme metamorphism and its rich content of silicates.

This main area presumably extends westward under the heavy cover of drift near Moriah Center but is broken up by hills of syenite gneiss. Patches of the limestone and their associates appear, however, for as much as 4 miles west of Moriah. The last exposure is at the ophicalcite quarry on the old road to the Schroon valley and south of Broughton ledge. To the southwest and north, the Grenville is cut out by the syenitic gneisses. To the south around Bullpout pond at the headwaters of Grove brook another small area appears, and extends southward into the Paradox quadrangle where it widens out very much into a broad area along Penfield pond.

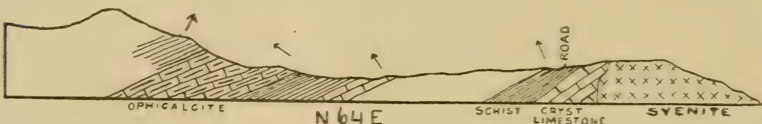

Fig. 15 Cross section of the Grenville strata at the Ophicalcite quarry, near Port Henry. The arrows indicate the strike in plan.

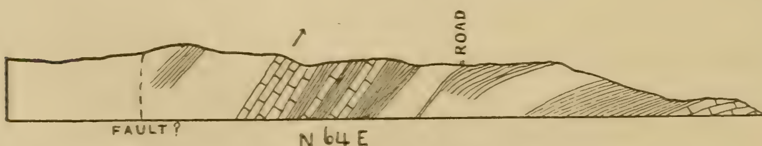

Fig. 16 Cross section of the Grenville strata 1 mile north of cross section represented in figure 15

Fig. 17 Cross section of the Grenville strata 2 miles west of Moriah Corners

In the way of structures it is not easy to make anything out of these exposures beyond individual monoclines. The exposures of the large area along the lake dip at flat angles westward. The remote portions after the interval of drift, show easterly dips. A broad flat syncline is suggested but the evidence is too fragmentary to be unduly emphasized. Apparently a flat series of sediments was invaded by the eruptive rocks which sometimes as intrusive sheets, sometimes as batholiths of irregular shape and size, broke them up, partially absorbed them, contorted them and separated them into the patches which we see.

In the case of two separated portions of this principal area interesting relationships exist. Thus as one goes from the shores of Lake Champlain westward across the outcrop of the Cheever ore bed an exposure of gabbro and syenite gneiss is traversed with the ore in the syenite and about 150 feet below Grenville limestone. Ore, syenite and limestone make a westerly dipping half of a shallow syncline and are cut off as nearly as can be told by a fault, beneath a meadow at the foot of the ridge which culminates in Bald knob. The ridge is a coarse granitic gneiss believed to belong to the syenite series and its summit is 800 feet above the Cheever mine. Yet on the west side we find the green syenite gneiss containing the Pilfershire ore bed which dips westward in syenite beneath Grenville limestone just as at Cheever. Apparently the ridge is a fault block, on each side of which the Grenville has been dropped.

For one who favored the sedimentary origin of the gneiss, here interpreted as syenite, an argument is offered by these relations which is not without its force. Thus a band of syenitic gneiss lies just below the limestone, with which it has a rather sharp but fairly regular contact, where seen along the lake shore just north of Craig harbor. At this point the Crag (or Craig) ore bed was reported by Ebenezer Emmons. A mile and a half north but farther back from the lake the same relations are repeated at the Cheever ore bed. The same distance west of Cheever, the same relations prevail at Pilfershire. Thus there would seem to be a fairly definite horizon, with the ore at about this position in three separate cases, and sedimentary stratigraphy is strongly suggested. Yet from the mineralogy of the walls and their close similarity with the wall rock at Mineville, which in turn reproduces the characters of syenites, elsewhere undoubtedly eruptive, the Crag, the Cheever and Pilfershire wall rocks are believed to be intrusive sheets rather than conformable beds.

Nearly 5 miles north of the large area of the Grenville, and across a complicated mass of eruptive rocks is another exposure in the valley of Stacy brook. Limestones, black, hornblendic schists and thin gneisses make up a series of outcrops extending across the valley. The structure is a monocline, with intrusives, north and south.

One of the most extraordinary of all the exposures is a very narrow belt in Split Rock mountain, north of Westport. It lies along the old road that led into the quarry worked many years ago in the anorthosite. The belt appears but one or two hundred yards in width and has anorthosite all around it, but it contains typical, coarse, white marble, and associated schistose gneisses.

Again to the north, and in the edge of this quadrangle, the Grenville appears, not, it is true, with limestones but with characteristic gneisses. The limestones are present, however, on Split Rock point and island, in the Willsboro quadrangle, next north and these two constitute one connected area.

Immediately west of Westport station an area of basic, thinly schistose gneisses begins and extends a mile or more to the southwest. They have undoubted gabbro on the southeast and equally well defined anorthosite on the northwest. No limestones have appeared in them, and their characters are not altogether demonstrated as sedimentary, but it is the writer's conclusion that they can be best placed here.

The remaining exposures are nearly all near Elizabethtown village and are small in amount. A mile southeast of Elizabethtown there is an exposure of limestone with a little magnetite associated with it. It seems to be caught in a mass of anorthosite. It is called the Steele ore bed and is illustrated under the iron ores, later on [fig. 30].

Again a mile and a half north of Elizabethtown in the western foot of Woods hill is another small ledge, heavily charged with silicates and with anorthosites just above in the hill. Still more interesting are the exposures 3 to 4 miles northwest of Elizabethtown in the southern portion of Limekiln mountain, whose chief mass lies in the Ausable quadrangle. In the Westcott quarry where the rock has been taken out for lime there is a ledge with 25–30 feet of limestone, only moderately charged with silicates, among which is wollastonite. Gneisses presumably sedimentary succeed on the west up the hill, still farther westward and across a high ridge consisting of a phase of the anorthosite; in the next gulch, a little limestone appears but again to the west a fine exposure was

found, rolling over in a low anticline and dissolved out into small caves. Anorthosite was found higher up after an interval of sedimentary gneiss.

In very much the same way as depicted here, the Grenville is found in the Ausable quadrangle to the north; the Lake Placid to the northwest; the Mt Marcy to the west, and the Paradox lake to the south.

Collectively viewed one can not form any other broad and comprehensive conception of the areas, than that they once formed an extended and ancient formation which was invaded by the overwhelming amounts of igneous rock, in the deeper seated portions of a great center of eruptive activity. So extended are the masses of the latter that only fragments of the Grenville remain with slight suggestions of original structure. So far as these can be deciphered however, the dips are prevailingly moderate and the ancient sediments appear to have been folded or tilted to only a moderate degree.

Areal distribution of the granites and related types. The chief area of these rocks is in the southeastern corner of the sheet. They constitute the abrupt fault block of Bulwagga mountain, and extend westward from its escarpment for nearly 3 miles.

The more northerly exposures are relatively small, numbering but three in all and believed to be in the nature of dikes or bosses.

North of the east end of Crowfoot pond in the ridge a quarter of a mile from the water's edge there is also a development of granitic gneiss, but it is so closely involved with the syenitic series that it has been regarded as an extreme phase of these rocks and has not been colored differently.

At best these rocks are minor members in the local geology, and the uncertainties of their relations have been set forth in the general description.

Distribution of the anorthosites. The anorthosites make up the western third of the area and are the rock of the high mountains. They sweep around on the north and constitute the northeastern corner. This portion sends a prong southwestward nearly to Mineville and embraces in its sweep an area of the other formations, including the Stacy brook Grenville. The anorthosites extend into all the bordering quadrangles in New York, except the Ticonderoga on the south, where they fail entirely. From the Elizabethtown quadrangle they cross a few miles into the Paradox lake, but then cease and are, so far as known, seen no more in the extended Precambric area still farther south. They culminate in the Mt Marcy

quadrangle next west, where they constitute the lofty peaks in this center of elevation.

In their structural relations they can only be described as a huge batholith or irregular mass of vast size. Whether there were successive intrusions of the typical anorthosites or not, no evidence has been found. There is visible mineralogical variation in the greater or less amounts of the pyroxenic component, and in the development of biotite in the exposures east of Elizabethtown, but this does not necessarily imply separate intrusive masses.

Where the borders of the anorthosites follow a stream valley their outline is quite certainly conditioned by faulting, and we might infer enough displacement to produce decided discordance, but this relationship is rare, and the fault lines usually pay slight attention to formational borders.

Pronounced eruptive contacts have been observed in several instances. In the cascades of Slide brook and Coughlin brook which enter the upper Boquet river from the west are very instructive exposures. Another that is more accessible is in the Branch just below the junction of the Windsor hotel road and the main road between Elizabethtown and Keene. From the bridge at the junction for 200 yards or so down stream to and beyond the mill the brook flows over the contact of the anorthosite and the dioritic gabbro while a small basaltic dike passes from one rock to the other, with very interesting illustrations of the effects of cooling. The relations are shown in figure 4, which is based on a pacing survey.

Aside from these intrusive contacts it is soon learned that the border of the anorthosite mass is almost always more basic than the central portions. Harris hill, a marked elevation in western Moriah, is an exception, probably because it is a fault block, but elsewhere these relations almost always hold.

There are two small outliers of anorthosite, neither a perfectly typical case of the rock, but both referable to this series much more closely than to any other. One is a coarsely crystalline garnetiferous variety at the western end of Crowfoot pond, where it is well shown in the talus. The other is farther west along the old road which passes Crowfoot pond. Since both occur in the midst of areas regarded as belonging to the syenite series, and since the latter are believed to be later than the anorthosites, the two small areas must be surviving islands or huge inclusions.

Areal distribution of the Split Rock Falls type. The main area of this rock lies along the upper Boquet river above New Russia.

It extends a short distance to the northwest and has an eruptive contact with the anorthosite, fragments of which it incloses. Its contacts with the syenite near New pond are not sharply defined.

Areal distribution of the Woolen Mill type. The most accessible locality of this type is in the bed of the Branch, about a mile west of Elizabethtown but the same rock runs to the westward, where it appears in the rather few exposures along the brook itself. It also constitutes the marked ridge which lies between the two Grenville areas at the northern edge of the map. It forms the summit of Cobble hill, and appears well down its flanks. The blue knots or augen of labradorite occasionally appear and serve to identify it.

The same rock has a fine development in Blueberry mountain along the southern edge of the sheet, where once again the blue labradorite knots appear in the basic gneissoid rock.

Areal distribution of the New Pond type. This interesting rock is much less abundant than the others just mentioned. Only the exposure along the road to New pond has been discovered except for loose boulders to the south and except for possible gneisses derived from it by shearing.

Areal distribution of the syenites. The chief area of the syenitic series is in the southeastern portion of the area, but a few scattered exposures have been noted in outlying portions to the northwest, which although not sharply marked are believed to be intrusive in their nature.

The syenites are believed to constitute a batholith of size covering 50 square miles or more and of irregular outline. Its contacts with the other formations so far as worked out are chiefly faulted ones, syenite on one side of the valley, anorthosite or Grenville on the other. As to the distinction between possible basal gneisses in the Grenville and syenitic members dragged out into gneissoid forms, the matter is difficult. The syenites are believed to be the chief wall rocks of the iron ores.

Areal distribution of the basic gabbros. Within the area of the present map there are 25 to 30 known exposures of the basic gabbros, the greater number of which are small. They can rarely be identified as actual dikes. They must be usually mapped without definite or characteristic shape, either from limited exposures, or because the outcrop actually presents the form of an irregular boss or knob. The largest area covers 3 or 4 square miles and lies east of Little pond which is itself southeast of Elizabethtown. The gabbro mass contains several bodies of titaniferous magnetite. Two

interesting exposures appear in the cuts of the railway on the shores of Lake Champlain, one north of Craig harbor and the other north of Cheever dock. The actual exposures of definite gabbro are not of themselves extensive but their intimate association with dark hornblendic gneisses has given rise to the view that the latter were derived from the former. The possibility that the gneisses may be basic syenites, to whose mineralogy they are more closely related and that the gabbro may be intrusive in them has but recently been appreciated. It seems not unlikely that the hornblendic stringers, so prominent in the Grenville limestones, may be derived from the syenitic rocks rather than the basic gabbros.

Areal distribution of the basaltic dikes. The dikes are general in their distribution and no part of the area can be said to be more abundantly provided with them than is another. Our knowledge of their occurrence is rather a function of extended exposure or of artificial excavations such as mines, than of variations in distribution. Undoubtedly there are many more undiscovered.

The one controlling feature in their structural relationships is the development of lines of weakness and as the master lines run northeast and southwest, it is along these that the basaltic magma has chiefly broken through. The dikes have been observed cutting each of the more extended formations here described.

Dikes of the same type of rock as those here described are much more numerous to the north. Professor Cushing has found them in great numbers in Clinton county and so far as we can judge this area is probably over the focal source or was most accessible from it. These dikes are known as far south as Fort Ann, but they appear to decrease in number to the south.

Chapter 8

AREAL DISTRIBUTION AND GENERAL STRUCTURE OF THE PALEOZOIC FORMATIONS

The Paleozoic rocks outcrop on the New York side of the Port Henry sheet in three separate areas, the largest of which extends from Westport 7 miles to the south a little beyond Mullen brook. The second is a little longer than 2 miles forming the site of Port Henry, while the third constitutes the Crown Point peninsula. The latter is the northeastern continuation of the Crown Point area of sedimentary rocks of the Ticonderoga sheet. These areas appear as embayments in the eastern margin of the mass of the Adirondack crystalline rocks and owe their preservation mainly to their being

sunk in deeply between the overtowering mountains of harder Precambric rocks.

The physiography of the Precambric mass of the Adirondacks is, according to Professor Kemp's investigations, mainly controlled by block faulting with the structure lines running principally in northeastern direction. Likewise, the Plattsburg area of Paleozoics has been found by Professor Cushing and others to possess as the main factors of its structure a number of meridional faults with connecting cross faults.

The Port Henry and Westport areas are identical in structure with the larger northern Plattsburg area. They are both, in the main, sunken blocks bounded on the west by distinct fault scarps where the harder Precambric rocks project above the less resistant Paleozoic rocks. This fault scarp is easily recognized in a vertical cliff that crosses the northern part of the village of Port Henry; and it is still more prominent in the Westport embayment where for at least 6 miles it forms a bold escarpment separating the wooded Adirondack region from the fertile shore plain in front of it.

The fault contact can be observed in several places in both areas. At Port Henry it is well exposed on the north side of Lock Lane where it is seen to dip steeply (50°) to southeast, and still better under the bridge of North Main street over Mill brook at the northern outskirts of the village. Here the Grenville limestone comes in contact with the reddish Potsdam sandstone along a northeasterly striking fault, the sandstone being dragged up along the fault plane and representing the downthrow. While in the Westport embayment the contact is not directly shown, in several places, as at Mullen brook, in the Stevenson (Elm brook) farm and northeast of Westport village, the Beekmantown rocks are exposed a few rods from the high bluffs of Precambric rocks to the west, the steep local dip of the dolomite at the same time indicating the closeness of a line of profound disturbance.

These meridional faults emerge from the Precambric rocks in the south and disappear again in them to the north. The north and south boundaries of the Paleozoic areas are mainly formed by cross faults. In the Port Henry block which has a triangular form the master fault, forming the western leg of the triangle, runs in northeasterly direction and plunges into the lake in Craig harbor while the other leg is formed by a northwesterly fault, both intersecting near the first Y of the Mineville Railroad, where the Potsdam reaches its maximum altitude in this area. The latter fault

while not seen is clearly indicated by the presence of Potsdam sandstone in the cut of the Delaware and Hudson Railroad south of McKenzie creek, close to and below the topographically much higher Precambric rocks, as also by the much increased dip (10°) of the sandstone. One cross fault is directly exposed in the Port Henry block in McKenzie creek just below the highway bridge, a little east of the Y of the Mineville Railroad. This fault strikes n. 5° e. and separates a white Potsdam sandstone on the west from a more massive pink sandstone with distinct cross bedding. The latter represents the older bed and the downthrow seems to be to the west of the fault plane. Several smaller cross faults are well exposed to the north of the railroad tunnel north of the village. One of these (striking n. 60° w.) shows a drop of only 2 feet to the north, which, however, is finely shown by the shifting of a bed of black chert in the dolomite.

The Westport block is bordered on the south by a transverse fault, striking n. 50° e. whose fault inscarp (here Potsdam) is well exposed in the woods above the railroad track. In the railroad cut itself the Potsdam is seen abutting against the Precambric rocks. Another cross fault is to be inferred to again separate this Potsdam block from the Trenton beds adjoining to the north of it along the deep depression of the lower course of Mullen brook. Still another cross fault, running in northwestern direction, cuts off the Potsdam and Beekmantown rocks from the anorthosite at the northern outskirts of the village of Westport.

While thus the boundaries of these two Paleozoic areas that appear as embayments in the eastern Adirondacks are formed by faults, except in the east where the rocks dip under the waters of the lake, the physical character of the rocks and their relation to the underlying rocks bear intrinsic evidence of their formation in shallow water and not very far away from shore lines. This is especially true of the Potsdam sandstone, which forms but a thin veneer on an irregular surface in the southern part of the Port Henry area, so that in several places hillocks of Precambric rocks penetrate the sandstone beds.

In the Westport area the prevailing dip is to the west and south of west, showing that the fault block is tilted toward the master fault. At the base of the fault scarp the dips of the Beekmantown beds are steeply to the east, owing to the dragging. Low folds and cross faults cause locally divergent dips as at the mouth of Hammond brook at Westport and at several places on the shore south

of Westport. The small block of Potsdam sandstone at the south end of the area is tilted in northeastern direction.

The presence of outcrops of Beekmantown beds west of the Chazy, Black River and Trenton belts of this area, directly in the strike of the latter [*see* below] necessitates the assumption of a branch fault of the master fault striking toward northeast. This fault is quite likely to come out under and be a factor in the formation of the drift-filled shore between Westport and Cold Spring bay.

The Port Henry block is mainly tilted to the east and northeast; but clearly much broken by smaller faults. Along the railroad and near the shore the beds lie rather flat, near the western fault scarp they dip, however, steeply to the east and near the southern boundary they dip equally strongly south, but close to the fault scarp (as in the railroad cut south of Port Henry) they dip strongly north. The strong easterly dip along the western boundary and the north dip along the south boundary are obviously both due to dragging. These dips hence support the conclusion of the presence of the faults that intersect at nearly right angles near the Y of the Mineville Railroad, forming there the highest point of the tilted fault block.

That also the Beekmantown beds at the north end of the area which seem to rest in regular succession on the Potsdam beds are much fractured is well seen in the railroad cut where especially the black chert bands bring out distinct fault lines with the downthrow to the north and a throw of but a few feet. A larger fault appears to separate the divisions A and B of the Beekmantown. This is indicated by a depression between them and the different dips. With these numerous orogenic disturbances is quite clearly connected also the brecciated condition of much of the Beekmantown dolomite. The chert bands of the railroad cut furnish here again instructive examples. They are seen to be bent very irregularly and broken into angular fragments in other places, at one point the contorted band having doubled around the fragments. It is to be inferred that the brecciated beds slipped when still under the enormous weight of the overlying younger Paleozoic rocks and, were faulted, and thus a crush breccia formed.

The Crown Point area is in its entire structure a part of the Vermont plain, as already recognized by Hitchcock, Brainerd and Seely and indicated by the continuity of the strikes across the lake at Chimney point. The northeast strike and northwest dip bring up the Chazy, Black River and Trenton beds in succession

along the north shore, thus producing a most complete and accessible section. The eastern portion is separated by a fault, first recognized by Brainerd, and traceable into Vermont. Its downthrow is to the east and the throw about 100 feet. The greatly different levels of the formation and the opposite dips of the blocks furnish also fairly conclusive evidence that an important, probably meridional, fault passes under Bulwagga bay. The configuration of Bulwagga mountain points to the same inference.

Chapter 9

GLACIAL AND POSTGLACIAL GEOLOGY

From the close of the epoch of the Utica slate, until the oncoming of the great ice sheet of the glacial epoch, we have no records other than physiographic. This fact would lead to the inference that land conditions prevailed during at least a great part of the time. If any sedimentation took place, the beds were again removed by erosion which must have been of very extended character. The faults which have broken the Utica as well as all the older formations can only be described as coming at the close of Ordovicic time or in the subsequent interval. It is natural to connect them with the upheaval of the Green mountains which occurred at the close of this period, but they may have been long after. The evidence of a Cretaceous peneplain has been earlier mentioned and its possible faulting during the Tertiary, but the evidence must be admitted to be extremely vague. There is little doubt that at the time the great ice sheet invaded the country from the northeast as the scratches show, the relief was much as it is now. The ice plucked away the loose rock and freshened up the escarpments; it sculptured amphitheaters and cirques and gave to the rocky exposures much of the rugged character which they exhibit today. In the closing stages the deposits of drift and the later postglacial clays served to smooth over this roughness in the depressions and made the rocky, glaciated district tillable and habitable.

In the preglacial times, the land must have stood at a higher level with regard to the sea. Lake Champlain obviously lies in an old river valley, whose bottom is now at least 300 feet below tide or 400 feet below the present surface of the lake. This elevation of 300 feet and more is probably but a small fraction of what really took place, as we have long since learned from the various submarine channels, opposite our large rivers, and from the drowned fjords such as that of the Saguenay. At all events we are locally assured of more than 300 feet.

Again the surface must have been depressed in the postglacial or closing glacial times much below its present altitude. In no other way can we account for the deposition in such great thickness of the Champlain clays. Consisting as they do of fine sediment which required deep and quiet waters, they indicate a decided submergence. They reach altitudes of 200–300 feet above tide in Westport and indicate a downward journey to more than this extent. They must have been deposited in an arm of the sea, because of the marine shells which are found in them, more especially in the town of Essex, just north of the present area. A rather impressive up and down swing of the surface is thus demonstrated.

While the data upon the glacial deposits as here discussed have been gathered when attention was especially concentrated upon the hard geology and while more definite details could doubtless be accumulated by special work upon this branch, yet the following record is made that the material in hand may at least become available. For the latter history of the Champlain valley we have the careful studies of Prof. J. B. Woodworth and those of Mr C. E. Peet which are subsequently cited, and which have been drawn upon in discussing these topics.

The glacial and postglacial deposits will be reviewed under the following topics: moraines, boulders, scratches, clays and sands.

Moraines. Glacial deposits in the nature of ground moraine are, of course, general throughout the more elevated portions of the area. The drift to the east of New Russia is very heavy and in the gulch of the brook which enters the Boquet from the east it is well shown. In the valley of Roaring brook 1½ miles and more from the Boquet it is also markedly in evidence. Again to the south of Mineville and in the broad upland upon which are located Moriah Center and Moriah all the bed rock except that in the pronounced hills is concealed. In sinking the Harmony shafts at Mineville over 200 feet of boulders and clay were penetrated before the work grounded on the rock. Terminal moraines or glacial drift in marked lineal distribution can hardly be identified but rather it seems as if a broad valley was filled up, the loose materials being packed in the depressions.

One extraordinary exhibition of boulder clay may be seen in the banks of Grove brook in the southeastern corner of the map, and just east of the cross roads which are a mile and a half from Lake Champlain. The clay is thickly charged with pebbles up to 3 or 4 inches in diameter, which are almost exclusively from the Black River limestone of the Ordovicic. This limestone is not of great

areal spread in this region and its nearest ledges are on the northwestern corner of Crown point. The direction thus indicated falls in line with the scratches mentioned under the next topic but one, and is directly opposed to an outward and expiring movement of local glaciation to the northeast. The road which formerly existed parallel to Grove brook has been destroyed by a freshet.

Glacial boulders. Boulders of moderate size which have been brought in by the ice sheet are of almost universal distribution. They, however, are of special interest only when they are of some rock of sharply defined character and one contrasted with the ledges on which it may rest. The most striking of the boulders consist of Potsdam quartzite, an exceedingly hard rock, of a pale yellowish color. Even on the mountain tops these boulders appear, having undoubtedly been derived from the Paleozoic lowlands to the northeast. The remaining Paleozoic formations are rarely seen, but in this and adjacent quadrangles all have been noted except Utica slate.

Anorthosite is a rock which is tough especially when crushed and recemented, and which lends itself readily to transportation. It is significant when found amid areas of contrasted formations. It is one of the most frequent boulders wherever there are anorthosite areas to the northeast. The syenitic and granitic gneisses are also common. A very few boulders of the crystalline limestone of the Grenville series and of the associated hornblendic schists have been observed but they are uncommon because of their poor resisting qualities and because of the relatively small areal distribution of the parent ledges.

A mile north of Port Henry and near the rose-quartz locality one small boulder of pink trachyte (or bostonite) was found. This rock occurs in several dikes in the Paleozoic strata at Essex and along the Vermont shore, especially on Shelburne point, but beyond a probable derivation from the northeast, its source can not be more sharply located.

As to the size of boulders the general range is from half a foot to 2 or 3 feet. Plate 12 illustrates one of fairly good size on the southern slope of Barton hill just below the ore bed. It is somewhat pear-shaped and is about 10 feet in diameter. The largest boulder noted, is in the woods, northwest of the Grenville area on Stacy brook. As paced off, it was 20 feet by 15 feet by 12 feet.

Glacial scratches. The scorings of the continental glacier which have been preserved are almost exclusively in the valleys and are best shown upon those surfaces of Beekmantown limestone which

have been covered until recently with clay and sand. On the exposed peaks and on the higher elevations where we would most desire to note the direction of ice movement, and where it was least influenced by the local configuration, the weathering of the surface has effectually destroyed the record. It may be therefore that the scratches remaining to us are the very last of the ice scorings and due to local glaciation. Nevertheless when they are all taken together throughout the region the testimony is the same. The direction is northeast and southwest and the ice invasion came from the northeast. This topic has been discussed by Dr I. H. Ogilvie in its general bearings.[1]

Back from the immediate shores of Lake Champlain, and in the area here mapped, glacial scratches have been noted in only two localities but as time goes by and observers are on the watch others will undoubtedly be detected. Just south of New Russia a rocky point projects into the highway from the west side and on it is a fountain. Upon this point the scratches are well shown and bear n. 52° e. true, or n. 62° e. magnetic. They run in this case parallel with the general course of the valley. In the extreme southeastern corner of the Elizabethtown quadrangle along the two northeast and southwest highways, scratches are well developed. The more northern instance runs n. 70° e. true or n. 80° e. magnetic and the southern one n. 65° e. or n. 75° e. magnetic. The local topography can have had slight influence in this case since the scratches are in a broad, open upland.

It is a striking fact that the ice sheet should apparently have moved against the hight of land, which it rode over. Dr Ogilvie reached the conclusion that the valleys were filled with stagnant ice, which bridged a passage for the great mass.

Clays and sands. Along the Lake Champlain shore the postglacial sediments are best developed in the Paleozoic flat south of Westport village and in Crown Point. The latter is so low, 140 feet as a maximum, that clays alone mantle it. Yet as noted by Dr C. P. Berkey, while in the field with the writer in 1908, the upper surface of the clay shows a curious downward slope from east to west, a relationship not easily explained by erosion. In the Westport flat the surface deposits reach the 300-foot contour but there is a marked accordance at 280 feet and several wave-cut ter-

[1] Glacial Phenomena in the Adirondacks and the Champlain Valley. Jour. Geol. 1902. 10:397-412.

races can be identified. They are relics of the postglacial Lake Vermont, the expanded predecessor of Lake Champlain as established by J. B. Woodworth[1] to whose work, and that of C. E. Peet, reference must be made for the interpretation of these phenomena as bearing on a wide area. The object, here in view, is rather to give to the reader a bird's-eye view of the region under discussion.

As to the thickness of the clays no very definite data has been obtained. Gulches cut them to a depth of 20 or 30 feet and the clays obviously go lower. In the Ticonderoga quadrangle on the south and in the northern portion of the town of the same name, brooks have eroded downward through fully 100 feet of clay. The depth is doubtless somewhat governed by the relief of the bed rock left on the retreat of the ice sheet.

Water-sorted sands are very much in evidence a mile or less west of Port Henry where Mill brook crosses the railway to Mineville. Very thick and extensive beds in the nature of delta sands have gathered from the 600 to below the 500 foot contour. They seem to have either been deposited against a lobe of ice which still filled the valley below, or else to mark a delta formed at a time when the waters stood at this level. The sands are deeply trenched by Mill brook and at periods of flood suffer severely. The present dam and pond used by the electric company have obliterated some of the exposures which were pronounced in former years.

Sands with more or less fine gravel appear in the Schroon valley and likewise in the valley of the Boquet river. The dunes of the latter have been mentioned in the opening pages as have also the deltas and lake bottoms. The correlation of the deltas would require more detailed study than has been given while working over the hard geology.

Chapter 10

ECONOMIC GEOLOGY

The chief of the mineral resources of the area here discussed is iron ore. Attendant upon the smelting of the products of the mines, limestone quarries have been opened in both the Grenville and the Beekmantown formations to supply the necessary flux. Some subordinate quarrying has also been done upon the serpentinous limestones of the Grenville for ornamental stone. There are besides these, great reserves of clay for the manufacture of brick

[1] Ancient Water Levels of the Champlain and Hudson Valley. N. Y. State Mus. Bul. 84. 1905. p. 190. *See also* the discussion by C. E. Peet. Jour. Geol. July-August 1904. p. 458.

should these ever be called for in the future. The several topics will now be described in order as follows:

1 Iron ores
- *a* Nontitaniferous magnetites
- *b* Titaniferous magnetites
- *c* Red hematite

2 Limestone
- *a* For flux, macadam etc.
- *b* For building and ornament

3 Clay

1 Iron ores

General commercial characters. The iron ores which are at present exploited are non-Bessemer and rather high in phosphorus. Magnetic concentration is employed to bring the phosphorus lower, and to a certain degree to raise the percentage in iron. Ores of Bessemer grade have been produced in the past and may any year be revived, since the deposits are far from exhaustion. Besides these two varieties, there is one other case of a magnetite rather rich in sulfur, an element which fails in the mines previously referred to. The ore was lean, however, and the mine, the Lee, near Port Henry, has been idle for years.

The titaniferous magnetites are a distinct and interesting type and are not at present of commercial importance within the area here covered, but they are not infrequent and are at least of great scientific interest. They are never as rich in iron as the similar ones farther west near Lake Sanford which are now about to be commercially mined and concentrated.

Red hematite has attracted attention in only one locality, just south of Port Henry, where it is the result of the decomposition of crushed hornblendic gneiss along a fault line. The pits have been abandoned and have been filled with water for years past.

The commercial importance of the iron ore deposits therefore hinges upon the nontitaniferous varieties, which are in some cases high in phosphorus, in others low. The predominant mining center is Mineville and from it the output really comes, but the revival of the Cheever mine north of Port Henry, with the aid of magnetic concentration has placed it again upon the list of producers, although the business depression of 1897-98 made the operation of the mill intermittent.

Geological associations. The largest mines occur in more or less gneissoid members of what is here described as the syenite

series, and the rocks are regarded by the writer as of igneous origin. The ore bodies must then be considered excessively basic segregations squeezed or drawn out into apparent beds. The largest of them exhibit a most extraordinary series of bulging folds and all are liable to rolls, pinches and forkings. Despite the igneous affinities of the wall rock the bedded shape of the ores has suggested to most observers a sedimentary origin so that this has been hitherto the most generally accepted view of them. The problem will be fully stated in the subsequent descriptions in association with which the points pro and con can be most significantly stated.

Several minor deposits are in granitic gneiss. Under this head belong the abandoned ore bed of the Essex Mining Company, south of Port Henry and the Lee in the outskirts of the village. One small occurrence, the Steele bed, just southeast of Elizabethtown, has Grenville limestone immediately over it. The cross section at the mine has been earlier mentioned when speaking of the distribution of the Grenville.

The titaniferous varieties are without exception in the basic gabbros. They form irregular masses, of indefinite shape and extension and of not very sharp definition against the walls. The ore is filled with the ordinary minerals of the rock and is merely a phase of the latter unusually rich in magnetite and ilmenite.

The mines and abandoned pits are all situated east of the great anorthosite exposures, and except for one or two outlying titaniferous bodies range along a belt which runs a little west of north from Port Henry, through Mineville to Elizabethtown. This arrangement does not appear to have any fundamental connection with any large geological feature and is doubtless fortuitous.

Historical outline of the iron industry

History. The first of the ore bodies to be discovered was the one which is now called the Cheever, but which when Professor Emmons was preparing his report, 1836–42, was known as the Walton or Old Crown Point vein [*see* Emmons's Report on the Second District, p. 237]. Nevertheless the name Cheever appears in Professor Beck's report on the Mineralogy of New York [p. 15]. The Cheever had been worked for 50 years when Professor Emmons visited it, and this would place its opening at 1785–90. The ore beds at Mineville were known in 1835–40, but the largest of them, as now revealed in the "21" mine (so named from the number of the old land lot) was first opened in 1846. It is evident that the

early mining industry was prompted by the call for ore for the small blast furnaces which still remain in states of indifferent preservation. Plate 13 is from a photograph of the old Colburn furnace which was built in 1848, and which still stands about a mile west of Moriah Center. Another one is represented by a pile of collapsed masonry, at Fletcherville, also called "Seventy five" a mile and a half north of Mineville. At Port Henry there was a furnace at Cedar point, even in Professor Emmons's time, and this is the site of the large plant now in full blast. Twenty years ago there were two other blast furnaces called the Bay State, and situated just west of the steamboat dock. The abundant slag along the shore at this point came from them, but they have since been torn down.

The old bloomaries or forges were located where there was a water power sufficient to run the blast and the trip hammer. But for 25 years or so they have been extinct. In their day they consumed an appreciable fraction of the output of those mines which were low in phosphorus and sulfur. The ore was hauled many miles to them. By 1890, except perhaps at Standish, in Clinton county they had practically gone to the scrap pile.[1]

a Nontitaniferous magnetites

Following the map [pl. 17] the ore deposits will be briefly outlined in order from south to north.

No. 1. This pit now abandoned was opened by Butler and Gillette and continued under the name of the Essex Mining Co. The work was based upon a band of ore and is represented by an excavation 40 feet long and 8 to 10 feet high, sloping at an angle of about 60° and striking approximately n. 12° w. magnetic. The dump alone reveals a rather lean ore with much hornblende and feldspar intermingled. The walls are reddish granitic gneiss. No analyses of the ore are available nor were any samples taken or notes recorded by B. T. Putnam for the Tenth Census.

In the hill standing in the angle of the highways and northeast of Bullpout pond there is a belt of attraction running in a northeasterly direction. It has led to the opening of some small pits. Attraction apparently extends for a mile, since on the northeastern

[1] A detailed account of the old forges and of the process will be found in the following: Egleston, T. The American Bloomary Process for Making Iron Direct from the Ore. Am. Inst. Min. Eng. Trans. 1880. 8:515.

side of the neighboring 1453 foot hill another small opening has been made. At the latter, the ore lies at or near the contact of a dark basic syenitic gneiss below and a light acidic gneiss above, just as at Mineville. At the more southerly openings the rock is again basic syenitic gneiss. Between the two the geological relations are somewhat complicated. Pegmatites and granitic rocks occur, suggesting that intrusive granites are present, as indeed they are in evidence on the southeast.

No. 2. Lee mine. This opening is just in the outskirts of Port Henry and in a little hillock with abrupt north and east sides which rise from a valley covered with sand. The nearest rocks both to the east and west are the Grenville limestones and their associates, but faults quite certainly intervene between them and the mine. Its wall rock is a granitic gneiss, whose dark silicate is biotite. It is reddish in color and somewhat different both in minerals and appearance from the greenish syenitic wall rocks, elsewhere met with the ores. The ore strikes n. 20° w. and dips about 19° westward into the hill at the more northern slope, but swings around to the southeast and steepens to a 30° dip on the south. B. T. Putnam visited it in 1880, for the Tenth Census [15:115], and has left a plan and sections. The mine is cut off on the north by a trap dike with an east and west strike. The dike can be traced across the hills to the eastward.

The pit is now full of water and serves as a dumping ground for refuse from the neighborhood. Putnam saw the mine when active and states that 9 feet of pyritous ore was displayed in the face. In old pillars a cross section can still be seen of lean, hornblendic ore. Putnam's analyses of samples from two lots, one of 2500 tons from the north slope, and one of 1500 from the south yielded the following. The sulfur, however, was for some reason not determined although it is the chief point of importance after the iron.

	1	2
Iron	45.01	44.38
Phosphorus	.047	.04

The ore is of low grade but the phosphorus is also low.

No. 3. Crag Harbor ore body. This is described by Ebenezer Emmons in the report on the Second District, page 236, as occurring in a cliff, 50 feet above the lake and half a mile below (north of) Port Henry and as being the most conveniently located of all the ore bodies in the region. It was 12 feet wide, in hornblende, and

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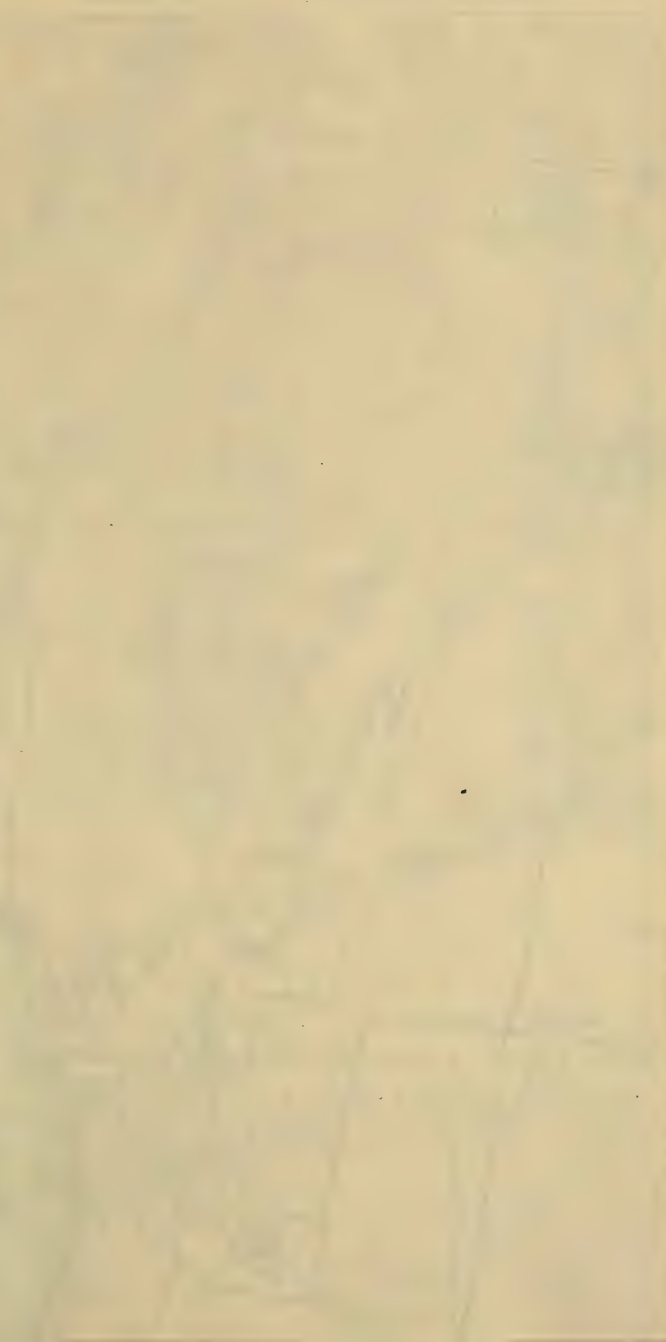

PARTS OF PORT HENRY AND ELIZABETHTOWN QUADRANGLES

MAP OF PORT HENRY AND VICINITY

The location of the mines is indicated by numbers which are referred to in the text

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dipped 35° west. The vein extended half a mile along the lake but the ore was pyritous, tough and difficult to crush for the forge. An analysis from Dr L. C. Beck's report on the Mineralogy of New York, pages 15 and 37, is as follows:

FeO	24.50
Fe_2O_3	66.80
$SiO_2.Al_2O_3$, etc	8.70
	100.00
Iron	65.23

This old deposit is no longer worked and has almost been forgotten. It occurs where the gabbros are a marked feature in the Delaware & Hudson Railroad cuts and it may be titaniferous. Since both Dr Beck and Professor Emmons speak of its difficulty of treatment the titanium may be the reason. Little was known of titanium in their time.

From Crag harbor for 3 miles northward the geological section along the lake shore is of more than ordinary interest. Partly from the original precipitous topography and partly from the cuts of the Delaware & Hudson Railroad, the exposures are excellent. The embayment of Crag harbor (called Craig on the U. S. Geol. Sur. maps) is due to block faulting, so that the northwest side is a precipitous wall. Above are the limestones and associated hornblendic schists and schistose gneisses of the Grenville. Below and with a sharp contact against the limestone is a massive hornblendic and feldspathic gneissoid rock in which are located the railway cuts. Immediately beneath the limestone is a band about 75 feet thick of a more feldspathic variety. Under the microscope it contains quartz and acidic plagioclase as the most abundant components. There is also a goodly proportion of orthoclase, often microperthitic and there are scattered shreds of brown hornblende. Below the last named and appearing in the railway cut is a more basic phase which consists, as the microscope shows, of plagioclase in broad crystals, orthoclase often microperthitic, a little quartz, rather abundant hypersthene and brown hornblende. It is a rock which could not have been derived from the basic gabbro. Its affinities seem to be quite close with the syenites. The dark green feldspar together with the abundant hornblende and hypersthene give the rock a basic look, beyond what the mineralogy of the slide would seem to warrant.

About 60 paces (or 6 rails) north along the track fine grained gabbro is found in the cliff, and at short intervals still farther

north rather coarse diabasic gabbro manifests itself. The contacts of the gabbro on the gneiss are not specially easy to decipher but they are believed to be those due to a succession of small block faults, which produce repeated exposures and which may readily lead the observer to infer the presence of more gabbro than is necessarily existent. The latter may well constitute only a relatively small dike or sheet.

In the first observations of this cut, and in several subsequent trips the writer gained the impression, not unnaturally, that a great intrusive mass of gabbro had entered through or beneath the Grenville series and that subsequent crushing and shearing had turned its southern and northern portions into gneissoid derivatives, leaving unsheared nuclei in the central parts;[1] but it is a better interpretation to infer an older intrusive sheet of syenite of acidic and basic bands, and refer to this the apophyses of hornblendic feldspathic rock which are so abundantly exhibited in the limestones and then to believe that later came the gabbro which was subsequently faulted in a way to give an undue impression of its amount.

The Crag Harbor ore then lies in the syenitic gneiss in almost the identical stratigraphic relations which are shown by the Cheever and the Pilfershire bodies.

One other possibility regarding the gabbro may be cited, which is one suggested by other very obscure relations which prevail between similar masses north of Cheever dock and on Barton hill, Mineville. It is that by the involution or infusion of a limestone mass the composition of the syenitic magma has been locally so enriched with lime as to attain the composition of a gabbro and to crystallize as such. On Barton hill it is almost if not quite impossible to detect the line where gabbro ends and basic syenite begins, and it is none too easy along the lake front, but while this explanation has been considered it has not been on the whole regarded with favor.

There is still a third hypothesis which falls in line with the views regarding the ores which have hitherto generally prevailed. It is, that the gneisses immediately beneath the limestone are not of igneous origin but are sediments in which the ores were deposited along with other sedimentary materials. The ore may have been magnetite sands, mechanically concentrated; or beds of brown

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[1] Kemp, J. F. Gabbros on the Western Side of Lake Champlain. Geol. Soc. Am. Bul. 1894. 5: 213, especially p. 221.

hematite (bog ores); or beds of spathic ore; any one of which in the subsequent metamorphism yielded the magnetite lenses. There is much apparent reason for this view. Thus the ore bodies resemble beds; they are folded exactly as stratified rocks are; they run long distances; and in the case of the Crag harbor, the Cheever and the Pilfershire they are at what appears to be a definite stratigraphic horizon, in hornblendic gneiss, a few feet below Grenville limestone, and that too although they occur at intervals over a distance of 4 miles, and with a mountain ridge between two of them.

The writer does not fail to feel the force of this association, and the argument is a strong one. On the other hand the mineralogy of the wall rocks of the ore is that of the syenite series, unquestionably shown to be intrusive in other portions of the Adirondacks. The gneisses might be intrusive sheets. If they are, the apophyses of similar rocks in the limestones are readily explained. The ores might be basic segregations in an eruptive rock and as such they might readily be drawn out into apparent beds; they might then be folded like sedimentary rocks. It is a curious fact that they appear in three cases in the gneisses near, although not at their contacts with the overlying limestones. In other cases, as at Mineville, no limestones are known within a mile of the ore, and from one to two thousand feet of overlying gneiss have been shown by the drill and the exposures. The Cheever ore is, moreover, so much like the Old Bed ores at Mineville that one is disinclined to think of one origin for one, and a different one for the other.

In discussing the Mineville ore bodies these general topics will be again referred to.

No. 4. Cheever mine. This, the oldest opening in the region, is situated about 2 miles or less north of Port Henry, and at its eastern edge, outcrops rather more than a quarter of a mile from the lake shore and about 300 feet above it. The chief workings are just north of a small east and west depression, through which a little brook passes into Lake Champlain, falling over a fine ledge of Grenville limestone, one of the best exposures in the region. There is certainly a great fault between the limestone and the eastern edge of the ore, since north along the railway the limestone gives way to greatly brecciated gneisses. Farther north again gabbro appears, but in irregular exposures mingled with hornblendic gneisses and quite difficult to understand. The ore itself, however, outcrops as a marked band or bed in green syenitic gneisses, and runs to the north for nearly a mile, with occasional

pits. The Cheever at the southern end is, however, the chief one. These workings, now being revived after years of idleness, dip down steeply, at 50° or 60°, then flatten at somewhat over 200 feet vertically from the surface and run westward until cut off by a fault. Their relations are shown on the accompanying section reproduced and reduced from the bulletin of the Geological Society of America 1894, volume 6, page 251. The only point of revision lies in the fact that our recent fuller knowledge of the basic syenite gneisses, makes the occurrence of unbroken gabbro

Fig. 18 Cross section at the Cheever mine, in a direction n. 60° e.

on the east doubtful. Field observations the past summer led to the conclusion that much of the black hornblendic gneiss, formerly taken for gabbro, is basic syenite gneiss, but massive gabbro does occur mingled with it. The ore is a band in the syenitic gneiss, here quite quartzose, and about 150 feet from the undoubted Grenville. Below the ore 50 feet of similar gneiss appears before the basic rocks take its place. As the ore bed is followed north the dip appears to flatten and in an old working about half a mile from the Cheever slopes, the strike is north and south and the dip 20° west. The same wall rocks, however, appear.

Another outcrop of ore appears along the present highway a quarter of a mile north of the old Cheever engine house. It strikes northeast and dips southeast. It has limestone not over 15 feet above it and while thus apparently stratigraphically higher or nearer the limestone than the position of the western end of the Cheever, if we consider it the same bed, it suggests a synclinal basin for the ore, with a pitch of the fold to the south. There can be no doubt that a north and south fault on the west beneath a meadow cuts off both the ore and the Grenville series in this direction.

The Cheever ore resembles very closely the Old Bed variety at Mineville. It is not quite so rich in phosphorus, but is still rather high in this element. Mr Putnam for the Tenth Census [15:114] took six samples, four underground and two from stock piles on the surface, which showed the following percentages:

Iron	65.33	63.5	63.86	64.42	64.77	63.08
Phosphorus	0.643	0.603	0.689	0.452	0.673	0.573

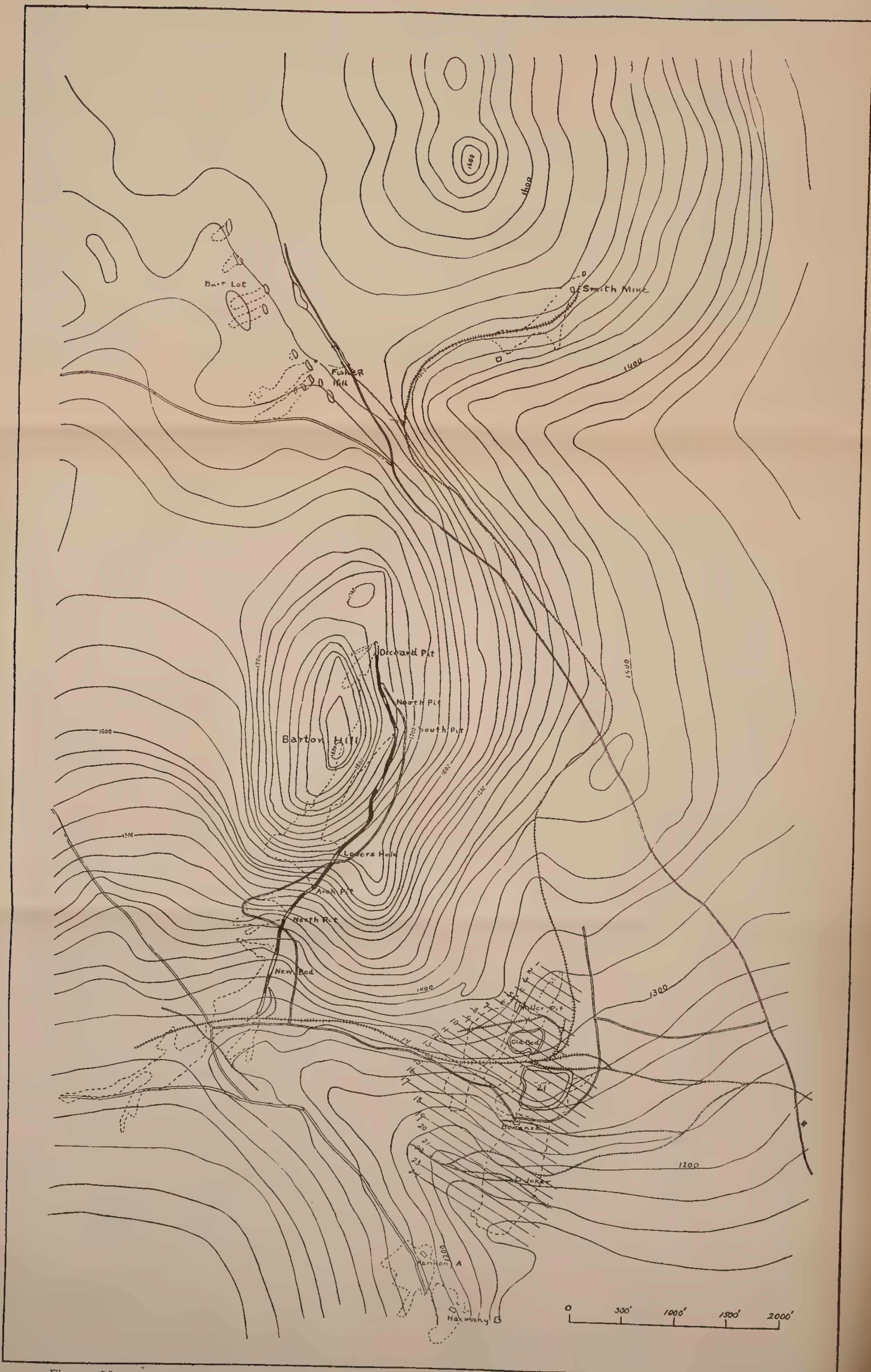


Fig. 19 Map of the vicinity of Mineville, to show the location and relations of the Old Bed, Barton Hill, Fisher Hill and Smith Mine groups. The parallel numbered lines refer to the sections, figures 20–27.

Titanic acid was found in five of the six, but its amount is very small. The ore is rich and, as shown by the analyses is of quite remarkable uniformity. In 1907 a magnetic mill has been built and concentration of the leaner unused ore has been undertaken accompanied by a reduction of the phosphorus.

Nos. 5 and 6. These two pits are called the Pilfershire. They lie at the western foot of the ridge which intervenes between Moriah Center and the lake. Not far above them is the Grenville with its limestones, and the relations are extraordinarily like those at Cheever. Even the gabbro appears not far to the eastward as detected by F. L. Nason, who has called the writer's attention to it.

The southern pit is a small one and of no apparent importance. The northern pits consist of three larger and two smaller openings. They strike nearly north and south and dip 60° west, passing below the highway 50 feet lower down. The wall rock is the familiar green gneiss which in thin section shows plagioclase and pyroxene. The mines are now abandoned and full of water.

The close parallelism between the geological relations here displayed and those at the Cheever is worthy of emphasis. In both the ore belt strikes nearly north and south and dips at about 60° west. It is in the characteristic green gneiss of almost identical mineralogy. Just above are the Grenville limestones. Just below but after an interval of gneiss is the gabbro. Between the two stands a ridge of old syenitic gneisses, with no Grenville involved and extending 2 miles without a break. Undoubtedly faulted upward, they make a mountain summit, 500 feet above the Pilfershire and 1000 feet above the Cheever.

Nos. 7 through 11. Mineville group.[1] A general outline of the relations of the ore bodies at and near Mineville, may first be given. There is one group of mines based on a large faulted and folded ore body in the village of Mineville itself. It outcrops at about the 1200 and 1300 foot contours and is the basis of several distinct mines, some of which are no longer worked. A half mile to the northwest Barton hill rises to an altitude of 1880 feet and on its eastern slope, and ranging from its 1300 contour to the 1750 is a long diagonal outcrop with many pits. The group, collectively

[1] In the preparation of these notes, every possible kindness has been extended to the writer by Mr S. Norton, general manager of Witherbee, Sherman & Co., Mr S. LeFevre, chief engineer, and Mr Rogers Hunt, assistant engineer. Mr Guy C. Stoltz, engineer for the Port Henry Co., has been equally courteous and helpful in affording data and advice regarding the adjacent properties.

taken, is here called the Barton hill. It is possible that this bed swings around to the east under the drift and is the basis of the two Harmony shafts, south of the Mineville groups [*see* map: fig. 19]. Yet there is still much uncertainty about this connection.

At the north end of the Barton Hill group a gap of concealed and drift-covered fields intervenes with no demonstrated ores. After half a mile, ore again appears in two bands one over the other, at the openings called the Fisher hill and Burt lot, both on the 1600–40 foot contours and now for 10 years or so idle.

A half mile east of Fisher hill and on the 1450 contour of another hill, is the recently revived Smith mine, whose ore body is tapped still lower down by the O'Neill shaft. Another interval ensues to the north and then after half a mile two old-time but long abandoned mines are met, called the Hall and the Sherman. The former is one of the oldest in this locality and is mentioned by Professor Emmons. Drilling has recently been in progress in exploring them, but no mining has been done for many years. Still farther north no ores are known for several miles.

Mineville group. These great ore bodies are the chief source of the local production, and they present a mass of noble proportions. Thanks to the liberal spirit and courtesy of the two companies, and to the excellent and careful records of the engineers they can be so well illustrated that with the solitary exception of the Tilly Foster mine in Putnam county, they give us the best idea of the general shape and relations of a magnetite body yet afforded in this country. At the latter the structural relations are simpler, and the amount of ore much less. The Mineville group presents a very violent case of folding, accompanied by stretching and pinching of the crest. The ores are in a pitching fold which makes depth rapidly to the southwest, so that we have to keep the relations constantly in mind in terms of solid or three-dimensional geometry. At the north end we have further to deal with a series of faults and a very puzzling relationship, which on the basis of one bed of ore is not easy to satisfactorily clear up. In the present description, the writer's paper and sections prepared in 1897 and published in the Transactions of the American Institute of Mining Engineers, volume 27, pages 146–204, are brought up to date and are made to include the results of 10 years of mining.

There are three principal and separate faulted parts of one great bed, viz: roughly from north to south, the Miller, the Old Bed or Mine 23 (the first discovered under the name of the Sanford pit) and the "21"-Bonanza-Joker continuous ore body, the chief

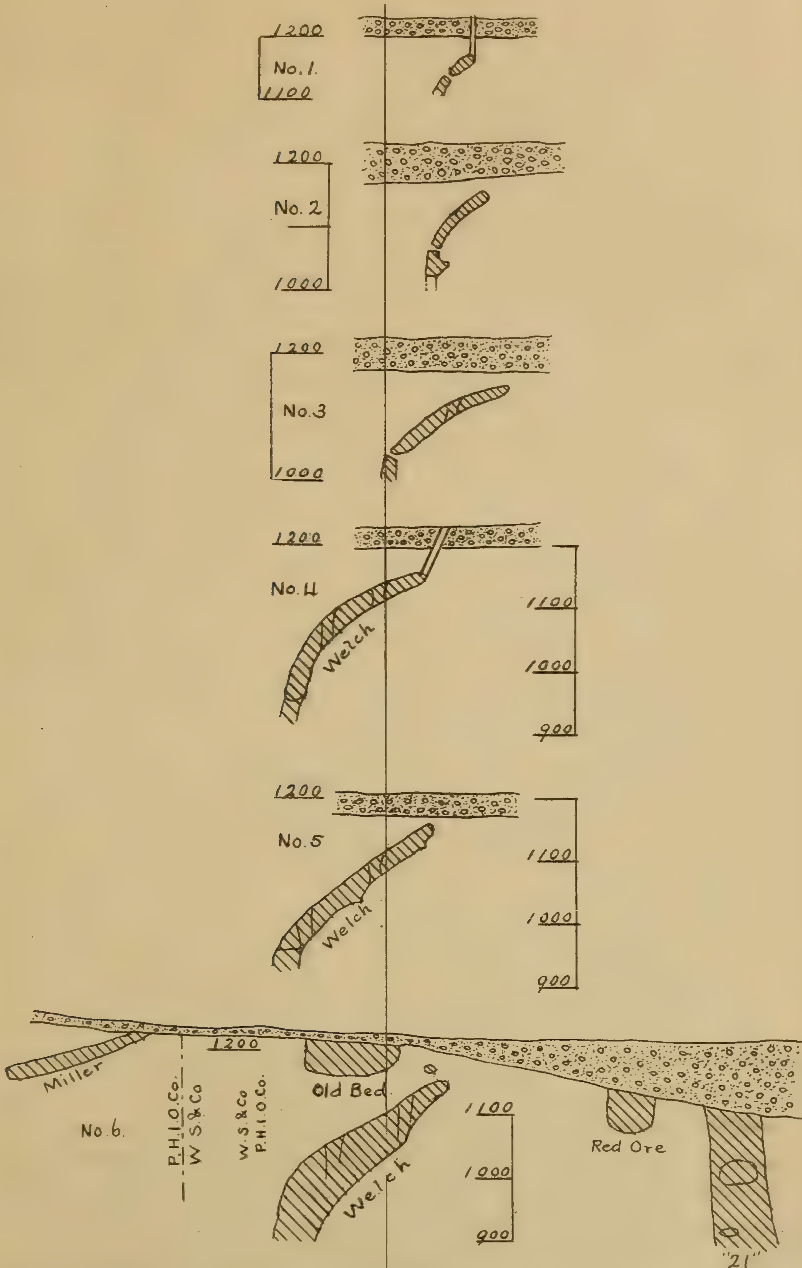


Fig. 20 Sections 1 to 6 of the Old Bed ore bodies, Mineville. Sections are 100 feet apart and drawn with the same vertical and horizontal scales. *See* figure 19

source of the ore. There are several shafts for Old Bed and "21" (named from the lot) and there are large open pits as well. The axis of the fold strikes about n. 30° e. true, and, as stated, pitches south. The full extent to the south has not yet been revealed. The sections here used are 24 in number, separated by intervals of 100 feet, so that they cover 2300 feet. The folded bed is broken by two main faults with strike a little more northerly than the axis of the fold, and apparently by one east and west fault under the skip way of mine "21." At least two trap dikes are known, running parallel with the main faults and probably themselves following additional small fault lines, while one other dike crosses the Joker at its southerly end in a nearly east and west direction. In the Harmony mines, the apparent prolongations of the north and south dikes are revealed. If now the reader follows the description with the diagrams beginning on the south with No. 24, the relationships can be most intelligibly stated [figs. 20–27].

Section 24 is largely inferential, but it is probably not far from the truth. The ore is a steep, vertical anticline, of which we know little except at the crest. In No. 23, which is more fully based on mining experience, a swell has developed in the eastern limb, and the two limbs have come together in depth. The drill has revealed a second and lower bed. In No. 22 the swell is still pronounced in the east limb, and a curious shoulder with an almost flat top has been revealed in mining. The lower bed continues as in the last section. In No. 21 the swell contracts somewhat, but the bulge toward the upper left-hand begins to assert itself, which is thereafter so marked a feature, and is apparently due to the stretching of a wellnigh viscous mass under irresistible compression, if indeed the rock was not still liquid from an original molten state. In No. 20 this upper left-hand bulge is much more pronounced, while the eastern shoulder is still very much in evidence. The intervening horse of rock has widened appreciably. In section 19 the upper western bulge has thinned somewhat, and has a very flat top, while the eastern shoulder has narrowed. It is very near the point where the Joker shaft first grounded in the ore. In No. 18 the upper western bulge has shrunk still more and the lower eastern shoulder has almost disappeared. Deeper mining has shown the true relations lower down on the limbs. We find them pinched together, so as to entirely circumscribe the horse of rock. In No. 18 also the sections first intersect the Miller pit as a small end of what soon

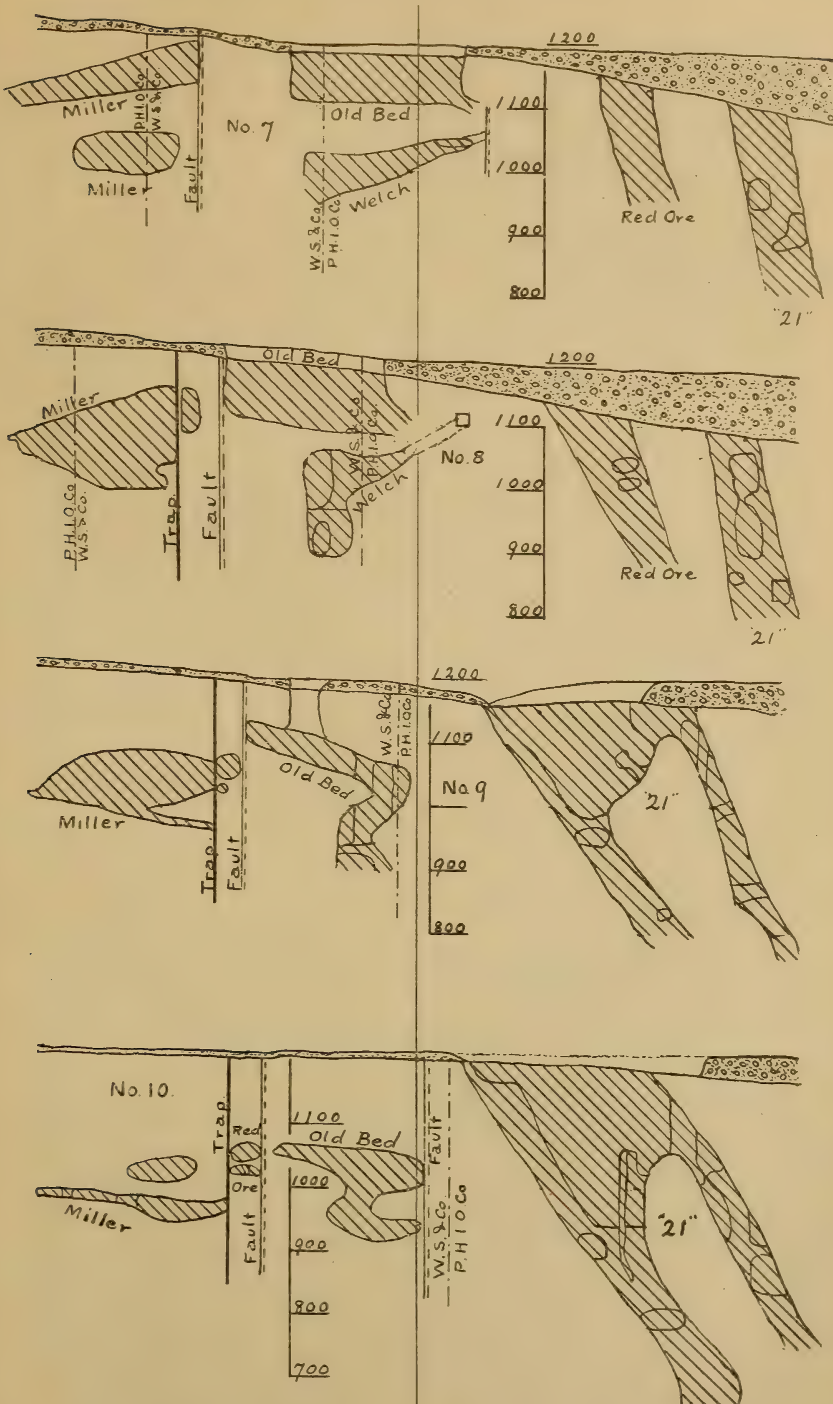


Fig 21 Sections 7 to 10 of Old Bed ore bodies, Mineville. *See* figure 19

becomes a large ore body. This can best be followed up by itself. In No. 17 the limbs have parted again, so far as yet indicated and the horse of rock has widened. The upper left-hand bulge has drawn in a little more. In No. 16 there is a bulge in the western limb, low down, but no very marked change in the other parts. In No. 18 we first encounter the property line and as developments have not been extensively made on the east side the data are not yet available. It is not an unreasonable expectation that the bulge in the lower right-hand limb of the earlier sections should manifest itself in depth to some extent in the as yet undeveloped portions to the north.

In No. 15 there is little change, but additional data as gained in the future will be of great interest. Between 15 and 14, a very remarkable change takes place. Apparently by a pinch and thrust from southeast to northwest a great bulge or wrinkle was rolled up on top of the anticline hitherto described, and just above its horse or core of rock. The old anticline soon pinches out but the new wrinkle bulges into a great second shoulder or roll, higher up than the one which we have hitherto followed. The latter gradually diminishes and in the end practically disappears between Nos. 12 and 11. Meantime the increasing bulge of the new wrinkle makes the noble ore body which was opened up originally in the Tefft shaft and in the great open cut of the "21" pit. The central horse of rock itself turns up to the vertical and, in the No. 13, even rolls over beyond it. All these features appear in sections 14 through 11. The upward trend or pitch of the axis of the fold now asserts itself strongly, and in Nos. 10 and 9 we see it almost reach the surface. Between 9 and 8 it emerges and thereafter the ore is in two separate limbs which run through No. 6. Beyond this point they have not been much mined in recent years, but, leaving faults out of consideration, we should expect the ore to be terminated only by the upward rise of the original outer or eastern edge of the great sheet of magnetite. This edge has been nowhere reached as yet in the deeper mining of the southern sections. It constitutes one of the interesting questions for the future to develop. As to the course of the western limb, when prolonged beyond the workings as yet opened up, it is probably faulted upward in the Old Bed-Welch ore bodies. That is, it probably flattens, encounters the fault shown in sections 13 and 14, is thrown upward and constitutes the Old Bed-Welch ore body with all the convolutions of the latter. If we turn to section 10 in which Old Bed was followed up to the fault line, at about the level of 940 feet, we can see that in order to allow

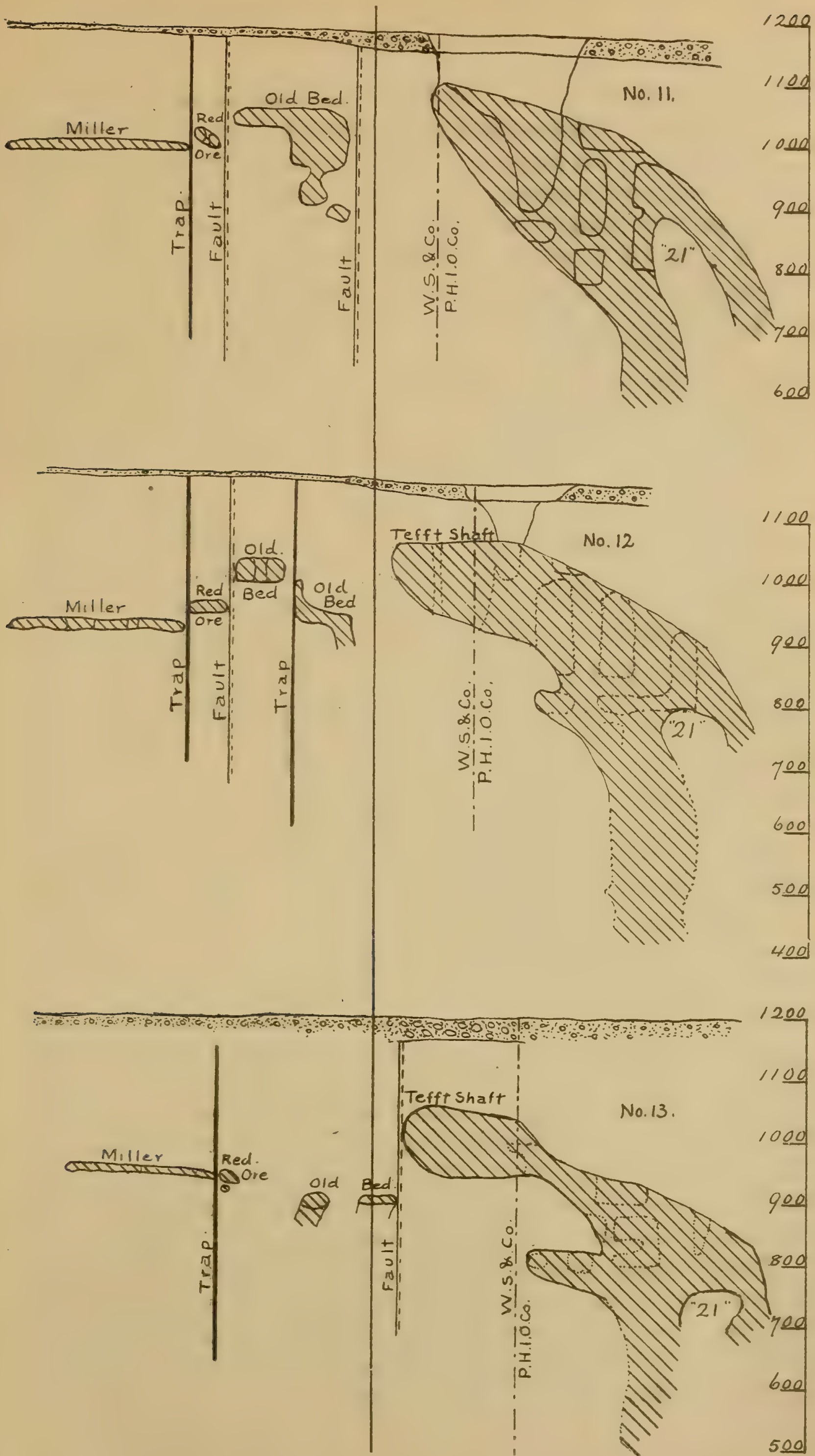


Fig. 22 Sections 11 to 13 of Old Bed ore bodies, Mineville. *See* figure 19

the western limb of "21" to flatten and come over to the fault, there must be a displacement of at least 300 feet. If the western limb of "21" rolls upward to the fault this throw will be diminished. We must not assume a purely vertical throw, since increasing experience brings home to us the conviction that almost always faults involve a diagonal shift along the fault plane.

Assuming therefore that Old Bed and Welch are the same ore body and are the faulted representative of the western limb of "21," an assumption which is corroborated by the similarity of the ores, we may follow out the curious convolutions presented by them. In sections 14 and 15 they are very indefinite and are mostly known by drill cores. The stray ore body shown in No. 15, on the center line, was revealed by a drill hole. Its identity is not known. The other one in No. 14, east of the fault and 200 feet below the Tefft shaft is also of uncertain relationship. Old Bed is first recognizable in this section, although little is accurately known about it. The ore grew small as followed many years ago and the workings were abandoned. In No. 13 Old Bed was found double, but again was not extensively opened. We know little about it. In No. 12 it develops a steplike roll of its own and is cut into two parts, by the small fault into which the trap dike has forced its way. At No. 11 the dike has pinched out and the fault was not noted. The ore is anvil-shaped and curiously pinched below. In No. 10 it is a reversed S-shaped fold and the core of rocks begins to manifest itself on the west, which is of great importance in the next sections. It is similar to those in the Joker-Bonanza "21" fold, but dips west instead of east. It rises toward the surface and ultimately cuts off Old Bed proper, from its downward prolongation, the Welch bed, until finally beyond No. 6, Old Bed runs out into the air and is lost. Meantime the Welch limb runs along and rises, with a lima bean pod cross section until it too goes into the air. Within the last year or two a new shaft has been sunk to tap the Welch ore on the line of section No. 1, so that we now know that this ore continues downward lower than was formerly shown. More recent data also show that in No. 7, rock cuts off the ore on the east, apparently before the upward curve of the ore was found and a fault is suggested.

In its western prolongation as shown in sections 8–12, Old Bed encounters faults and an area of broken ground with one or two disconnected masses of iron-stained, apatite-bearing ore called "Red Ore." The red color is due to the crush and to the consequent alteration of some of the minerals. In the slides the color

Plate 18

The mills at Mineville, N. Y. looking northeast. The Joker shaft is on the right; the Bonanza shaft on the left.

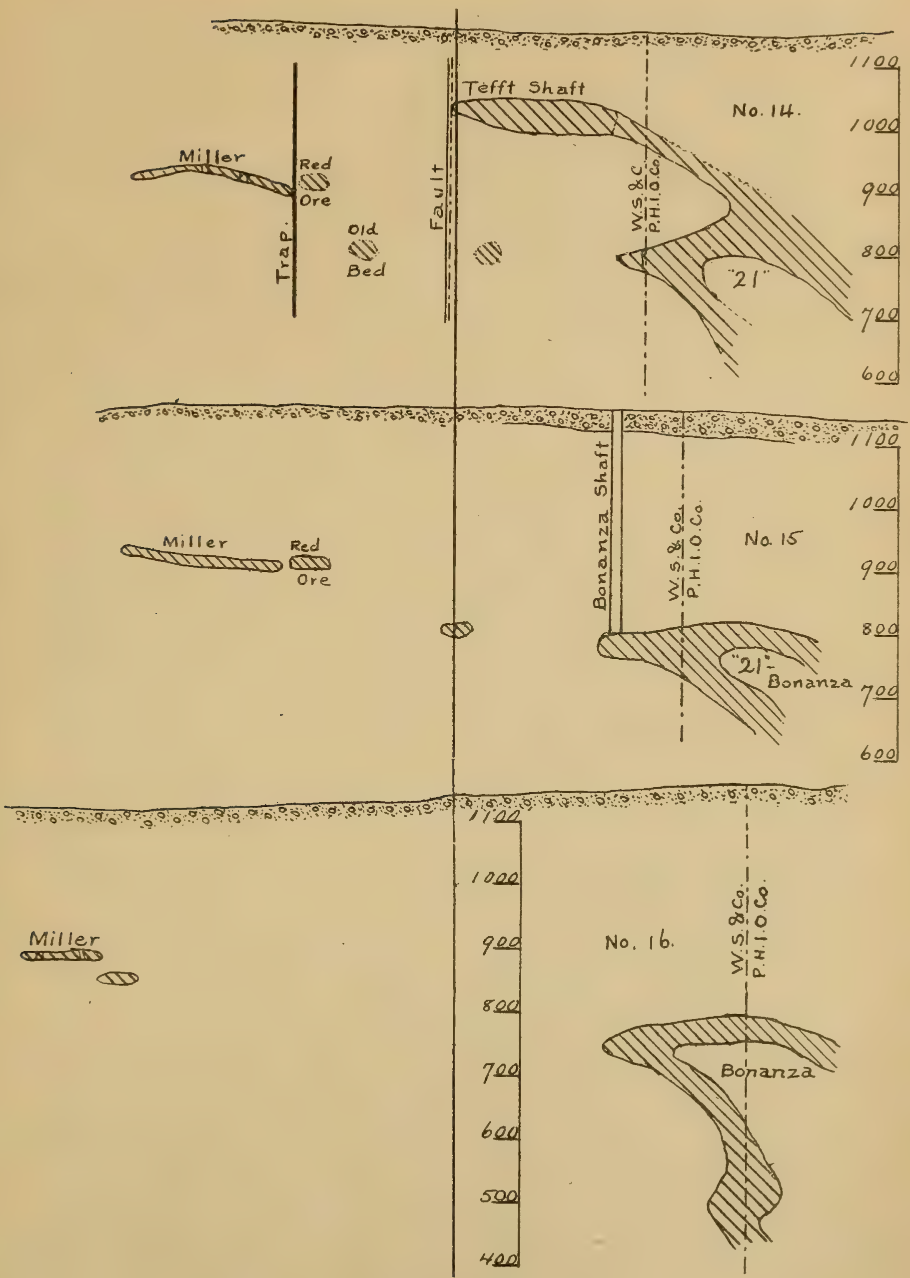


Fig. 23 Sections 14 to 16 of Old Bed ore bodies, Mineville. *See* figure 19

is clearly shown to be caused by red hematite infiltrations into cracks. The source of the iron oxid is without doubt decomposed pyroxene crystals.

Beyond the "Red Ore" lies the Miller pit, a very large and very interesting ore body, now practically worked out. The Miller is presumably the faulted extension of the Old Bed, which is dropped to the west, but it has in sections 7–10 a very peculiar double character. The separate parts of No. 7 coalesce in Nos. 8 and 9 and part again in No. 10, beyond which to the south the upper one, once the large one, fails entirely. We are confronted with some difficulties in following out the folds in whatever way we may try to explain them. We must consider the Miller as an expanded prolongation of Old Bed before folding; that is that the Miller was longer north and south, so as to allow for its extended pod in sections 13–18. Probably the under one of the two pods in No. 10 was connected with Old Bed and was doubled over on itself as shown in Nos. 7 and 8. It must either have been this or else the upper member is the prolongation and the bed was doubled under itself to account for Nos. 7 and 8; or else the Miller is a forking pod, from a central thickened portion in Nos. 8 and 9, where the two parts coalesce. Any of these three relations is possible, but if we favor folding we can not avoid giving great emphasis to the viscosity or doughlike consistency of the rocks at the time, since in no other way could they possibly have bulged and molded themselves into these forms. So pronounced is this character that one can not well help giving serious attention to possible convolutions in a molten but ropy mass. Under the latter assumption we need infer burial in the earth at a less depth in order to make the results possible.

The following analyses illustrate the composition of the ores from the "21" pit. No. 1 was a sample of 65 carloads and No. 2 of 35 carloads from the Port Henry Co.

	1	2
Iron	60.03	60.91
Silica	4.48	4.49
Phosphorus	1.635	1.548
Sulfur	.021	.027
Titanium	.12	.03
Copper	....	.007
Moisture	.28	.25

When the phosphorus is recast as chlorin apatite, it gives for No. 1, 9.14, and No. 2, 8.83. Calculating all the iron as magne-

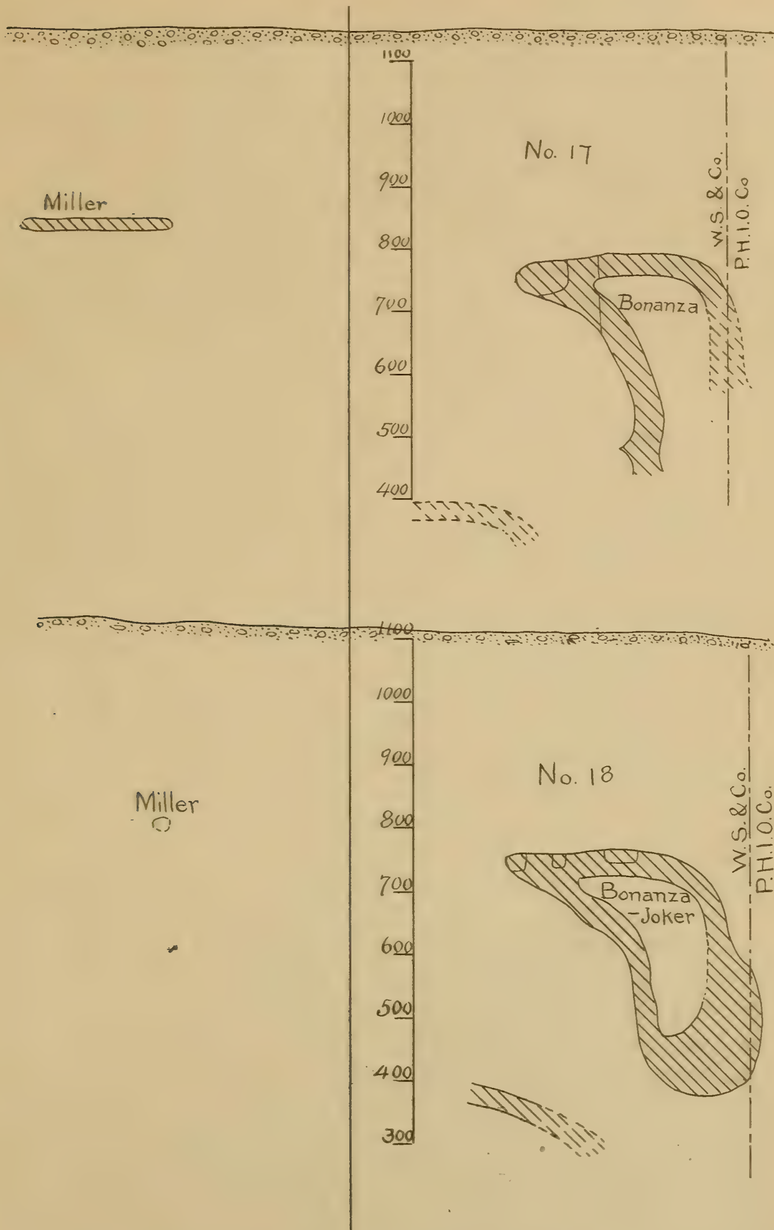


Fig. 24 Sections 17 and 18 of Old Bed ore bodies, Mineville. *See* figure 19

tite, this mineral then formed in No. 1, 83 per cent of the mass; in No. 2, 84 per cent. In the sample and undetermined there was more than five per cent of CaO, and probably a little Na_2O, attributable to the green pyroxene often observed in the ore.

The analyses below, taken from the *Iron Age* of December 17, 1903, show the composition of the crude Old Bed ore and the products made by its concentration at the milling plant of Witherbee, Sherman & Co. No. 1 represents the crude ore, No. 2 the magnetic concentrates, No. 3 the first grade apatite product made by retreatment of the tailings from the first concentration, and No. 4 the second grade apatite product.

	1	2	3	4
Iron	59.59	67.34	3.55	12.14
Phosphorus	1.74	.675	12.71	8.06
Bone phosphate	......	....	63.55	40.30

Harmony mines. The most recent developments at Mineville are the two Harmony shafts, A and B, which were sunk 5 or 6 years ago in order to tap a bed of ore revealed by the dipping needle and the drill to the south and somewhat to the west of the Joker workings, and at a much higher horizon. The Harmony bed strikes northwest and dips southwest at a rather flat angle. It is 10 to 20 feet thick and is cut by at least 3 narrow trap dikes with a strike a few degrees east of north and a vertical dip. They fork somewhat and are not absolutely continuous. The dikes occupy small faults of 10 to 50 feet displacement and strike in a direction to suggest that they are the same as the two in the Miller pit.

The relations of the Harmony ore to the Joker on the one side and the Barton Hill group on the other are interesting. Our last section of the Joker is 500 feet above Lake Champlain, while the outcrop under the drift of the Harmony bed, 400 or 500 feet away, is 450 feet higher. If the latter is the prolongation of the former there is a very great fault in the interval. On the other hand, if we attribute to the Barton Hill group a swerve to the eastward under the cap of drift, there is a very strong probability of connecting up with the Harmony bed. There is unexplored ground in between with evidence of some disturbance. The composition of the Harmony ore as regards phosphorus is intermediate between the Barton Hill and the Joker. It is higher than the former and lower than the latter. The percentage in iron is somewhat less than the Joker.

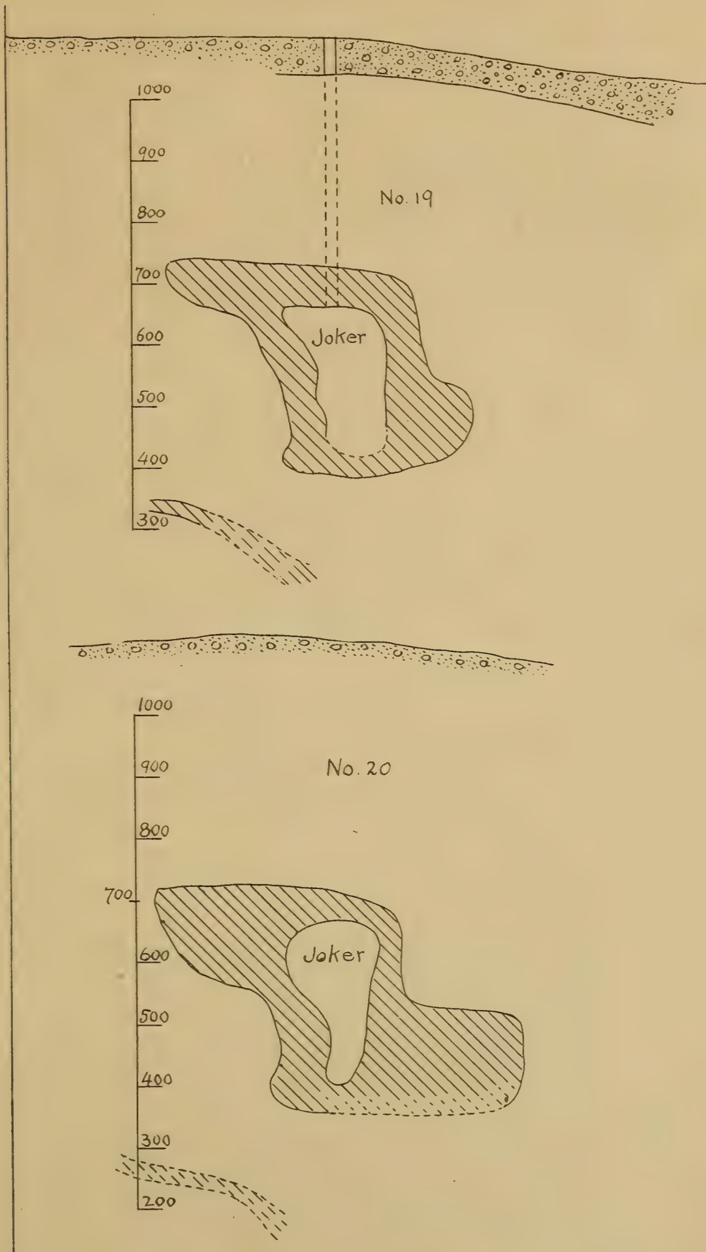


Fig. 25 Sections 19 and 20 of Old Bed ore bodies, Mineville. *See* figure 19

A third possibility must be considered, namely, that it is a totally distinct bed having no necessary connection with either of the older ones. While it is natural to seek to connect those already known, it must be admitted that the last view can not be entirely ruled out.

Barton Hill mines. These openings are distributed along a practically continuous bed whose outcrop is approximately 3500 feet long in a direction a little east of north. From the 1300 contour on the south, the outcrop rises to the 1750-foot contour on the north. From the southern end of the outcrop the underground workings follow an extended shoot of ore some 2000 feet farther on a flat dip to the southwest; and along its axis this particular branching pod must be fully half a mile long.

Taking the Barton Hill bed as a whole it is characterized by swells and pinches giving the enriched and thickened shoots which have been specially followed in the mines. Their axes and therefore the workings run northeast and southwest and are closely parallel with the Old Bed group, and with the Harmony beds. No doubt the relationship is due to the general system of folding which prevails in the gneissoid rocks and which has caused the rolls and attendant bulging. Upon the map of the Mineville area [fig. 19] the successive openings are given. They begin on the south with the New Bed, which is the deepest and most extensive. Then follow the North pit and the Arch pit, of moderate extent. From the Arch pit a tunnel is now being driven northwest on a slightly ascending grade so as to bring out by a gravity tram, the ore which may be tapped in the downward extension of the more northerly shoots. Already some gratifying discoveries have been made.

The next pit on the north is the Lovers Hole, the famous opening from which came the extremely rich ore and the remarkable crystals of magnetite, mined about 1887–88. A total of 40,000 tons from one chamber averaged 68.6 per cent and carload lots ran 72 per cent, being almost chemically pure magnetite.

Beyond the Lovers Hole is a stretch not much mined as yet, and then as the outcrop swerves with the contours to the northwest, there are three pits, the South, the North and the Orchard. The rock dumps are large at this end, indicating leaner ore. Beyond the Orchard pit, there is an interval with no mines, and mostly with concealed bed rock, for half a mile. Within this distance there is a drop of 150 feet in the altitude and then two groups of mines, now for some years unworked, are found. These are the

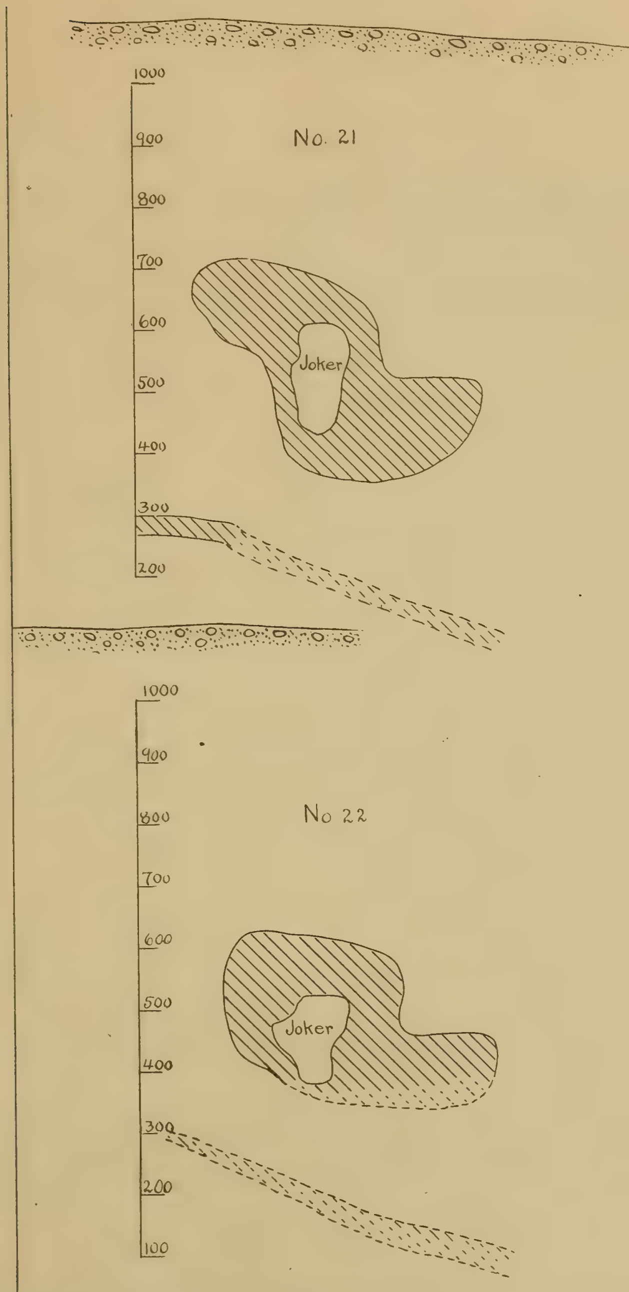


Fig 26 Sections 21 and 22 of Old Bed ore bodies, Mineville. *See* figure 19

Fisher hill mines belonging to the Port Henry Iron Ore Co., and the Burt lot, of Witherbee, Sherman & Co. The ores are rather lean but are of Bessemer grade.

The pits are distributed across a horizontal stretch of 100 feet at Fisher hill and 250 to 300 feet at the Burt lot. They dip about 25° westward, and are therefore something like 40 feet apart vertically at the former and 115 feet at the latter. There are no marked horizons of ore within these limits. At Fisher hill the workings are 600 or 700 feet down on the incline, and at the Burt lot, 300 or 400. The railroad has been dismantled for 10 years past and the mines have been allowed to fill with water.

It is quite possible that the Fisher hill and Burt lot ores are a reappearance of the Barton hill bed after a lean interval, and that they mark a northerly continuation of the latter. It is very natural to infer these belts and especially are we prone to do so in so far as the time-honored sedimentary conceptions of origin influence us. The northern pits are double to a degree not shown by the southern, and if we are influenced by the igneous views, we may not feel justified in inferring the identity without proof of the connection. The wall rocks are practically identical and the general dip and axial trend of the pods correspond.

To the east of Fisher hill and a half mile away upon the eastern slope of a different hill is another great lens or pod now known as the Smith mine, and actively worked by Witherbee, Sherman & Co., through the Cook shaft. This pod was discovered by the needle. It does not outcrop. It dips west and pitches south like the others and furnishes a non-Bessemer ore much like Old Bed, but lower in phosphorus. A vertical shaft taps the upper end of the pod and then from the foot the two skipways fork and proceed southwest, one going for about 1000 feet. The ore varies from 20 to 40 feet thick, and at the south drops over 600 feet below its high point on the north. At the southern end is the old O'Neill shaft, now used for pumping and in the fall of 1907 tapped by the northern workings.

Two hundred feet or so north of Cook shaft, is the Thompson, long abandoned, and beyond this an interval of some distance with no workings. Recently diamond drilling has, however, revealed ore, which may in time be worked. The hill then abruptly drops away to a small valley, on whose northern side are two old mines, the Hall and the Sherman, which were early discovered but which have long been idle. The property has passed to Witherbee, Sherman & Co., and has lately been drilled. Ore has been found

Plate 19

Fisher Hill mines when active in 1896

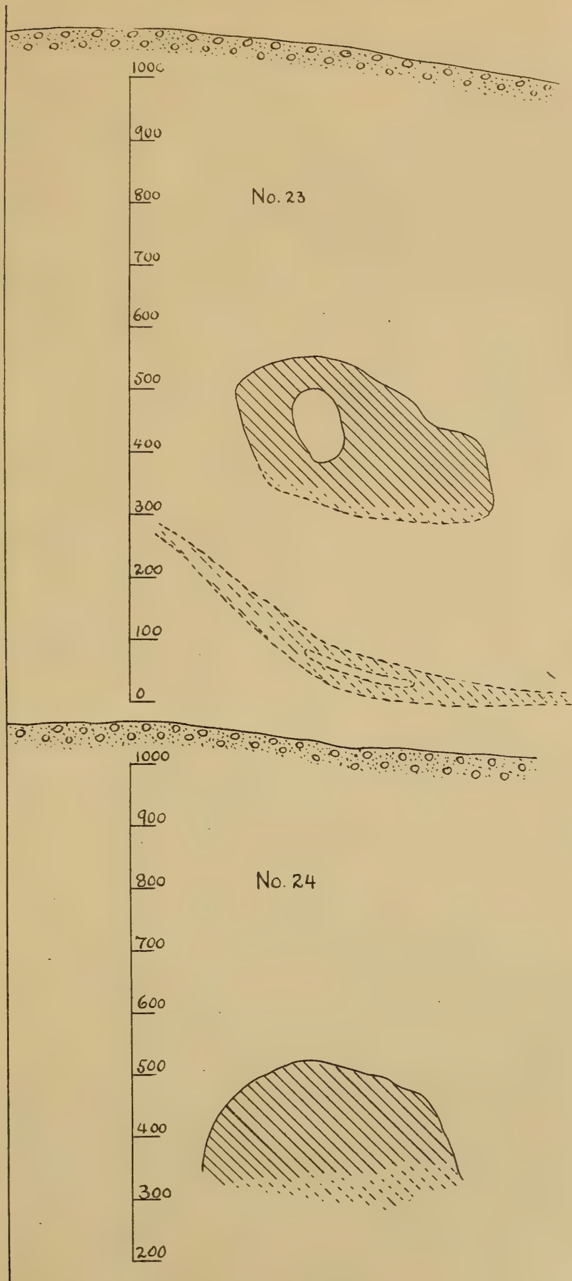


Fig. 27 Sections 23 and 24 of Old Bed ore bodies, Mineville. *See* figure 19

in rocks the same as at Mineville, and constitutes a reserve for the future.

It is natural to consider these last mentioned beds the northern extension of the Smith mine, and it as representing the Old Bed group, farther east and lower down than the Barton hill-Fisher hill-Burt lot series; but inasmuch as the O'Neill shaft is over a mile from the last exposure of the Old Bed series with almost no outcrops between, and in rocks that are practically massive, one may quite as well regard the northern ones as totally distinct ore bodies. Again one's train of thought is necessarily influenced by the sedimentary or igneous views of origin. The axial trend of the Smith mine is parallel to the same feature in all the others to the south, and therefore shows the same great structural character, presumably due to folding, whose compressive strain being at right angles to these axes, operated in a northwest, southeast direction.

Geological relations. Up to the time of the appearance of the writer's paper on "The Geology of the Magnetites near Port Henry, N. Y., and Especially those at Mineville," in the *Transactions of the American Institute of Mining Engineers*, 1898, volume 27, pages 146–204, the wall rocks of these great ore bodies had been generally described as "gneiss," and had been with entire justification regarded as the usual run of these ancient metamorphics which habitually contain the magnetites. By mapping of each outcrop and parallel observations underground and by microscopic determinations it was shown that there are several distinguishable types of gneiss present, and one intrusive gabbro. In the "Old Bed" group, of which the "21" mine is the chief, the hanging wall is a very light colored acidic variety which was called the "21 gneiss." It is a granitoid aggregate, consisting essentially of microperthite and quartz. With these and in subordinate amounts are plagioclase, magnetite, titanite and zircon. Of the last named magnetite is the chief, and often the scattered grains might easily give the observer the impression that they are some dark silicate. Still, were a stray crystal of the emerald-green pyroxene also to appear, it would not be surprising, although one is rare. An analysis of the rock is given on pp. 49 and 50 and a recasting for its mineralogy.

Additional study of many drill cores, and further observations in the mines have served to corroborate the above determination.

The great ore body lies beneath a cap of this very acidic rock. The "21 gneiss" appears at times at other horizons in the series but it is not always accompanied by ore. It is moreover very similar to the wall rocks at Hammondville, if not actually identical with them.

Fig. 28 Old Bed ore. The black is magnetite; the stippled mineral is apatite; the lined mineral is emerald-green pyroxene. Actual field 0.1 inch.

Beneath the ore appears a more basic variety, rich in hornblende, augite, and sometimes in biotite. Plagioclase is abundant and inasmuch as massive gabbro is seen beneath the Barton Hill ore, the basic gneiss was believed to be a metamorphosed representative of it and was called "gabbro-gneiss." Meantime, however, we have learned much regarding the syenitic series of the Adirondacks and have also obtained some thousands of feet of drill cores not previously seen. From the latter it is evident that representatives of the former are the chief members in the series. Many more slides of the supposed "gabbro-gneiss" serve to ally it with basic developments of the syenite series and it is much more defensible to consider the ores as lying between the two extremes, an acidic and a basic, of the great syenite series. In the basic we find so much microperthitic orthoclase that it is practically impossible to draw sharp lines of distinction among these varieties when starting from the normal syenitic type.

In the early paper a band of acidic gneiss was identified in the hanging wall of the Barton Hill group, and was called the "Orchard gneiss" after one of the pits. The rock was composed essentially of quartz and plagioclase with now and then a few magnetites and zircons. One related occurrence had microcline. This must be regarded as essentially a phase of the "21 gneiss," since in the one case the albite molecule crystallized as spindles in the orthoclase, yielding microperthite, while in the other it combined with a little of the anorthite molecule to yield oligoclase. The Orchard gneiss is soon succeeded, as one ascends Barton hill, by a darker variety containing microperthite as the most abundant mineral, with quartz, oligoclase and orthoclase as the other light colored components. The dark minerals are brown hornblende, emerald-green augite and rarely hypersthene. Apatite and magnetite are also

present. This was called the Barton gneiss. It is obviously the characteristic syenite of the Adirondack area as repeatedly described in later years by Cushing, Smyth and the writer. The additional study of the drill cores but serves to confirm its abundance in the series.

Lying below the Barton Hill ore body and between the Arch pit and the Lovers pit, is a goodly exposure of typical basic gabbro, so that there can be no doubt that this rock is represented in the hill in an important way. Exposures are fragmentary because of the ever present glacial drift, but the typical and unmistakable gabbro is succeeded as one follows along to the north, by a dark, basic and at times garnetiferous gneiss, which one might naturally and with great reason regard as a metamorphosed form of the gabbro itself. This was the view taken in 1898. Repeated and painstaking study of the exposures since then, and due consideration of the basic phases of the syenite series and of the character of the feldspars, which are largely orthoclase, have led to the conclusion that this basic gneiss belongs rather with the syenites than with the gabbros, and that the gabbro as seen is a separate intrusive mass. Yet it must be said that there are very puzzling things to be seen. Thus as one follows along the foot wall of the ore above the Lovers pit and toward the South pit, there are exposures of dark, gneissoid rock, apparently basic syenite, yet with many little garnets like the gabbro. Again beyond this point there is rock which is believed to be true gabbro as mapped in 1898. Yet as to the shape of the gabbro intrusive mass, no conclusion could be reached. It is involved in the basic gneiss, and so poorly exposed because of drift, that it is very easy to begin to speculate as to whether a mass of absorbed limestone might not locally change a syenitic magma into one gabbroic in character. Practically the same relations, equally puzzling in character, appear on the summit of the hill above the Smith mine, where garnetiferous basic (syenite) gneisses are again associated with gabbro in a very obscure manner.

In the close observation of this hillside below the Lovers pit, the writer also happened on what appeared to be a small dike, about 10 inches thick, striking with the schistosity of the basic syenitic gneiss, but cutting it on the dip. It is a quite acidic rock, and reveals in the slide, quartz and orthoclase as the most abundant minerals, less oligoclase, and a few shreds of dirty green hornblende, so molded around the other minerals as to suggest either crushing and dragging or secondary crystallization. There is a

little magnetite and a stray zircon or two. The rock is much more acidic than the walls within which it is found, but its mineralogical affinities with the acidic phases of the syenite are close.

It seems inconceivable that a little dike should occur alone, but no other eruptive masses have been detected with which to connect it.

Pegmatites. The ore bodies are occasionally cut by pegmatite dikes of a very coarse character and of interesting mineralogy. They are chiefly quartz and orthoclase, although oligoclase enters also into the aggregate. In the walls of Old Bed pegmatitic developments are characteristic of the edges and limits of the ore body and contain also coarse hornblende and large, coarse crystalline magnetite. They seem in some way to be associated with it in origin. In the "21" pit streaks of pegmatite run parallel with the general foliation and again give the impression of having been intimately involved with the ore at the time of formation. Allanite appears at times in these pegmatites and presumably from these or from others somewhere in this pit, Prof. James Hall obtained a superb crystal which was formerly in the collections at Yale University [Dana, E. S. On a Crystal of Allanite from Port Henry, N. Y., Am. Jour. Sci. June 1884. p. 479].

Ten years or more ago, in mining below the present floor of the "21" pit a large pegmatite vein or dike or mass was encountered, whose relations to the ore are not accurately known to the writer. Many tons of it were thrown on the dump and it was found to be rich in zircons, at times of rather large size and of great perfection. Much less frequent arsenopyrite also appeared and one specimen of a black coaly mineral, obviously one of those containing the rare earths, but not sharply determined. In this mass of pegmatite allanite strangely enough has not been detected. Magnetites of the familiar lamellar growth, with layers parallel with the octahedron faces, are abundant.

In the lower workings of the mines on Barton hill pegmatitic bodies of very interesting character have been encountered, some of which are now exposed in the new tunnel, which will further develop these lower lying ores. One mass of white fluorite with magnetite disseminated through it is cut by the tunnel and entirely forms one wall for a sufficient distance, to raise the question of its utilization. In other places in these workings white quartz and disseminated magnetite appear of obvious pegmatitic affinities. On the dumps of the North pit, scapolite enters into other pegmatitic lumps whose exact source in the old workings is

unknown. In a similar way large red garnets were at one time revealed in these same pits.

In the Smith mine, however, and from the Cook shaft which taps the northern end of this ore body, some of the most interesting pegmatite has been revealed. It consists of very coarse quartz and feldspar, with which allanite in irregular crystals up to the size of one's hand is richly disseminated. Rarely good terminations can be obtained, but the mineral is so brittle that it can not be freed from the matrix except by the exercise of great care [*see* Ries, H. Allanite Crystals from Mineville, Essex County, N. Y. N. Y. Acad. Sci. Trans. 1898. 16:327–29]. The dump is chiefly the product of early mining, although some pegmatite has come up in carloads of recently excavated waste rock.

These pegmatites and their associated minerals, some of them at least unusual in this abundance, are strongly suggestive of igneous phenomena and to the expiring stages of some intrusive mass they would naturally be referred. If, as seems most reasonable for Old Bed, "21" and Barton hill, we connect them with the ore, they must mark an attendant phase of its separation. Otherwise they must have come from some separate intrusive mass at a greater or less distance and one which it is not easy to identify. The basic gabbros would suggest themselves.

One can scarcely attribute the pegmatites to regional metamorphic processes.

Revision of local geology. The geologic map here given shows somewhat different relations in the Barton hill area in regard to the distribution of the gneisses and gabbro than were shown on the map published by the writer in 1898. It also introduces the syenite series as embracing the several gneisses called "21," "Orchard" and "Barton." The syenite series has been described on earlier pages, with analyses and calculations of mineralogy, which will serve to make the significance clear. As stated in the general discussion of the syenites, the ores are regarded as basic segregations in an eruptive mass of this character.

Origin of the ore. In all our work hitherto the gabbros have been believed to be the latest intrusive of the larger masses. That they penetrate the anorthosites as dikes is certainly true, because among others the great dike at Avalanche lake — at the source of the Hudson — shows these relations. As against the Grenville series they are also believed to be intrusive, although decisive contacts are not so clearly shown as with the anorthosites. But since the anorthosites are known to be later than the Grenville and older

than the other eruptives, there is no doubt that eruptives which cut the anorthosites are themselves later than the Grenville.

When we come to the relations of the gabbros to the syenite series, especially in the vicinity of Mineville, there is much obscurity. When field work was first done by the writer in this area, the syenites had not been recognized as such, and the rocks, which we now believe to be embraced under them, were called hornblende-gneiss or augite-gneiss. In these gneisses the gabbros when discovered were believed to represent intrusive masses whose boundaries, because of lack of exposures, could not be delimited or discovered. They were so involved with hornblendic gneisses that the latter were believed to have been derived from the gabbros. But as already outlined very careful revision of the exposures along Lake Champlain and on Barton hill, coupled with close microscopic study of the drill cores, has shown the following relationships. From the normal aggregate of feldspar and augite or hornblende, or, less often, hypersthene, the feldspar predominating, the syenites develop into basic bands in which the dark silicates are in excess. Yet there is no marked difference in kind of minerals, only a change in relative abundance. Garnets also appear, though not frequently, and the rock becomes indistinguishable to the eye from somewhat gneissoid derivatives of the gabbros. In the writer's former paper [1] gabbros were mapped on Barton hill near the Arch pit and again farther north near the Orchard pit. Between these exposures of undoubted and typical gabbro there is the stretch of dark basic rock, which we also associate with the syenites. Careful study has failed to show any recognizable contacts between the two, or more than a gradual transition. One can not say where the one ends and the other begins. Either the basic syenitic phases develop at times into gabbros, possibly by infusion of limestones from the Grenville or else the gabbros have been in some places metamorphosed to hornblendic rocks indistinguishable under ordinary examination from basic phases of the syenite.

In the belief that the basic gneisses beneath the ore represented the gabbro elsewhere seen in the foot wall in its massive form, the writer developed in the former paper the interpretation of the ore as a contact effect of the intrusive gabbro. In the present paper the immediate wall rocks of the ore bodies have been consistently described as members of the syenite series. With this change goes inevitably a modification of the earlier interpretation of origin.

[1] Am. Inst. Min. Eng. Trans. 1897. 27:146.

Rather than contact developments along an intrusive mass of gabbro, they have been spoken of as basic segregations in syenites. Both these interpretations are opposed to the still older belief that the ores are of sedimentary origin and the question may be perhaps stated with the arguments pro and con at this point. It is the more appropriate because among those actively engaged in mining and widely also among geologists having occasion to deal from time to time with other magnetite bodies in the Adirondacks, the rocks and associated ores are regarded as sedimentary in origin.[1] The writer while favoring the igneous conception disclaims any personal bias toward it, other than that it has seemed to be the simplest and least objectionable interpretation of rocks, confessedly puzzling.

The ores do certainly imitate to a marked degree the folds and similar structures of the stratified rocks, with perhaps this qualification that the folds are of an extreme type, being overturned, stretched and doubled up together in a very violent way. If sedimentary they must have been folded under such extreme pressure that the rocks flowed after the manner of viscous materials. In no other way could the Tefft shaft ore body have been pinched away from the main mass of the "21" pit. These folds are undoubtedly not essentially different from others well recognized in regions of metamorphosed, sedimentary rocks. The cross sections of the Alps for instance show many cases of the same sort.

On the other hand if one imagines a molten magma, differentiated into layers of contrasted composition, layers which range from acidic extremes to basic, then squeezed into folds either while yet viscous or after consolidation, the result would be the same. That this differentiation takes place in magmas is one of the growing convictions of students of eruptive rocks. It is certainly well enough established to justify giving it serious consideration. It may perhaps not unjustly prevent us from taking the sedimentary nature of the rocks as positively established because of the folded structure.

Another feature which has been esteemed proof of the sedimentary origin is the persistence and faithfulness of the ores in stratigraphic position. In the case of the Barton Hill group, they certainly do extend as much as a mile on the strike and are persistent for this distance. If we unwrap the Old Bed group from its folds and reconnect the faulted blocks they will extend,

[1] See for example W. L. Cumings, "On Sedimentary Magnetites." Engineering and Mining Journal. July 7, 1906. p. 25.

in one dimension at least over half a mile. This is certainly on the face of it suggestive of sedimentary stratification, but in fairness we might say that it could also be derived from a persistent, differentiated layer in an igneous magma. It is of itself scarcely conclusive on either side.

Another feature is the podlike distribution of the ore, affording its swells and pinches, and its tendency to a shinglelike distribution of the larger ore bodies. This structure is most pronounced in the Barton Hill group and is less evident in the Old Bed series which, as thus far developed, are more like one enormous folded pod. As long ago as 1881, the relationships of ore and lighter minerals in the tailings of mills, which were engaged in concentrating iron ores by wet processes, impressed H. S. Munroe[1] as imitating the lenticular shape very clearly and the same relationship has been noted by others since. The concentrated black or magnetite sands, which we not infrequently observe on beaches and along rivers draining areas of magnetite-bearing rocks, are likewise suggestive. They have given much support to the sedimentary view, and it is not so clear that heavy layers of eruptive origin would assume these forms, unless compressed strongly while still viscous. It must be admitted that while not perhaps conclusive, yet the lenticular shape does accord best with sedimentary deposition.

Another consideration, which must be emphasized in the interpretation of the rocks, concerns their mineralogy and their parallelism with other known cases. There is no doubt that the most abundant rock in the cores has exactly the mineralogy and the texture of the syenites as elsewhere identified. H. P. Cushing has shown these syenites to be beyond question intrusive in their nature. They contain fragments of the Grenville series, undoubtedly caught up in a molten mass. They present irruptive contacts with the anorthosites, penetrating the latter in dikes and tongues. Their mineralogy is essentially that of the eruptive rocks, the augite and hypersthene especially being foreign to the metamorphosed sediments. While the ores are often intimately associated, especially with the very acidic phase, described above, and while both these varieties differ from the normal syenite, yet they are so involved with it, that it is quite impossible to believe that they are sedimentary and the syenite eruptive. They all hang together in one essential whole or entity and it is almost impossible to regard one

[1] School of Mines Quarterly. 1881. 3:43.

as different in origin from the other. The syenite has practically convinced the writer that being igneous itself, it carries inevitably into the same great group of rocks all the associated rocks, whether they consist of acidic, or basic silicates or even of ore itself. Hence this consideration is esteemed of greater weight than the coincidence of the pod or lenselike shape with undoubted sedimentary structure, and, in the interpretation of the nature of the ore bodies, the preference is given to igneous processes.

If we grant for the moment that the ores are of igneous origin and endeavor to understand the possible causes which have led them as well as the more basic and the more acidic phases of the syenitic rocks to form, we find ourselves confronted by great obscurity. It is believed by many that some sort of segregative process leads to this separation, just as pots of nickle-copper matte rearrange their composition in a fairly constant way in the few moments of cooling; or as pigs of base bullion, homogeneous when molten, are diverse when chilled. Some kind of physical-chemical force must assert itself and produce the variation. In connection with igneous iron ores, whose common mineral magnetite and its associated apatite are the first components of a fused magma to crystallize, many have thought that these two, being heavier than the magma, have settled out by gravity and have become concentrated as soon as developed. Subsequent flowage might then drag them out into bands, and rearrange their position with regard to relative depth. It is interesting to note the occurrence of the ores immediately beneath very silicious layers at Mineville, but the silicious or "21" gneiss as it now stands does not represent sufficient normal syenite to have yielded the vast quantity of magnetite now found in the ore. The separation must have taken place elsewhere. In a viscous flowage, it is conceivable that the bulging folds might have been yielded under pressure, and some of the difficulties afforded by such extreme local folding of sedimentary rocks may be avoided.

In June 1909 in the *American Journal of Science*, page 421, F. E. Wright and E. S. Larsen published a very interesting and significant paper entitled "Quartz as a Geologic Thermometer." The point of importance is this. When silica crystallizes above 800° C. tridymite is the form assumed, but when it crystallizes below 800° C. quartz is the result. Furthermore when quartz develops between 575° C. and 800° C. it assumes one division of the hexagonal system (apparently the trapezohedral-hemihedral); while the quartz which forms below 575° C. falls in another divi-

sion (the trapezohedral-tetartohedral). As a result of these differences, certain contrasts of physical and optical properties arise which cast light upon the temperature at which any individual quartz has crystallized. Experimental tests have shown that the quartz of veins and pegmatites is prevailingly of the variety below 575° C., while the quartz of granite and related igneous rocks belongs in the variety above this critical temperature. The two may be distinguished by certain optical properties and by etching.

As a test of the nature of the rocks associated with the magnetites, the writer asked Dr F. E. Wright to make some trials of their quartzes. With great kindness Dr Wright consented to do so and obtained the following results in the laboratory of the Carnegie Institution in Washington.

Specimen 196A came from diamond drill hole 196 in the Lower Bonanza mine and was a piece of core from a point a foot or two below the ore. A dark hornblende or pyroxenic variety lies immediately beneath the ore, but within a foot or two the dark silicates decrease giving the more feldspathic and quartzose specimen which was tested. Five plates were cut of which three had the characters of the quartz below 575° C. and two those of the variety above this temperature. Dr Wright inferred that the quartz on the whole rather favored the low temperature variety formed near the critical point 575° C.

Specimen 196C came from the same drill core about 72 feet below the ore. The rock was considered a typical case of the syenite. Seven plates were cut, of which five favored the high temperature variety, and two the lower form. The conclusion reached was that these quartzites probably formed not far from the critical temperature of 575° C.

Specimen 140IV was taken from the core of hole 140, located west of the Harmony A mine. The hole cut a thin bed of magnetite. Ten plates were cut of which five were characteristic of high temperature quartz and five of low. Probably, as in the other cases, the temperature of formation was not far from 575° C.

Seven plates were prepared of the lean quartzose ore from the Nichols Pond mines described below. The tests indicated that this quartz had never reached 575° C.

These lines of evidence are not so decisive as was hoped but at all events they indicate that the rocks have passed through quite exalted temperatures. If not positively those of igneous fusion they are none the less so high as to preclude the mere burial and metamorphism of sediments. Thus if we allow a normal increase

of temperature of 1° C. for each 100 feet of descent, we call for 11 miles of depth to reach 575° C. This is beyond the belief of a conservative mind and forces us to the assumption of some localized source of heat, i. e. intrusive rocks. We may think of the ore as being more or less akin to pegmatites in its formation, and of the walls as perhaps being formed somehow under the influence of mineralizers so as to require less exalted temperature of crystallization than normal eruptives, but igneous phenomena and influences in some form we can not reasonably escape.

Unsatisfactory as the available suggestions of origin may appear, it should always be realized that we are dealing with very obscure and difficult questions at best, and with rocks of great age and of complicated history. To whatever portion of the world we turn for the results of similar studies, we find geologists involved in the same difficulties. The best that one can do is to present a candid statement of the case leaving for the future such further light as the general advance of the science may afford.

Nichols Pond magnetite. From 3 to 3½ miles north of the Fisher hill and Hall mines, there was formerly active a small enterprise based upon an exposure of magnetite on Campbell mountain

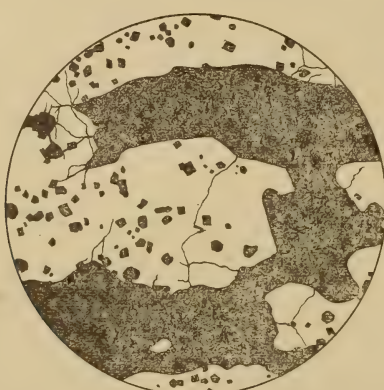


Fig. 29 Lean magnetite, Nichols Pond pit. The white is quartz; the black magnetite. The aggregate resembles a quartz vein with magnetite. Actual field $\frac{1}{10}$ of an inch.

a mile west of Nichols pond. The principal open cut is practically on the summit of the mountain so that from it one looks away to the north across the valley of the Black river. According to J. C. Smock [N. Y. State Mus. Bul. 7, 1889, p. 36] operations were begun in 1845 and continued to 1850. The openings are on lots 166 and 168 of the Iron Ore tract. Either at this time or later a concentrating mill was erected upon the shores of Nichols pond

and a tramway was built across its northern end which passed eastward descending some 700 feet in about a mile and a half to the first highway in Westport.

The deposit is lean and lies between acidic and basic gneisses very like the Mineville succession, if not identical with it. So far as one could judge, subject to local attraction, the strike was n. 35° w. true, and the dip 60° west. The section of the large and more northerly pit is as follows:

1 Hanging wall, typical, green massive syenite.
2 Lean mixture of magnetite and quartz, 12–15 feet thick. This is illustrated in figure 29 drawn from the microscopic slide. This association is unusual, and has not been elsewhere seen.
3 Still leaner mixture of the same general character, 20 feet.
4 Compact, feldspathic rock, 15 feet.
5 Lean mixture of magnetite and quartz, extending under cover.

The open cut was 75 to 100 feet long, 50 feet across, and had a wall about 25 feet high at the back. To the south, on the old road to Nichols pond, is another pit 15 x 15 feet. Hornblendic gneisses, presumably syenitic are shown in the foot wall, but the hanging was concealed.

Professor Smock states that the ore was reported lean and titaniferous, but the association with quartz would make the last statement unlikely. Professor Smock did not visit the mine. The leanness and remoteness are sufficient explanations for the cessation of operations.

Gates and Noble mines. Along the easterly front of the ridge which lies between Lincoln pond and New Russia there are several abandoned pits which were formerly operated to supply the forge at New Russia. Professor Smock in Bulletin 7, page 34, places the Gates mine on lot No. 138 of the Iron Ore tract. No work has been done since 1882. Professor Smock states, "The ore has been opened a length of about 20 rods, and in one shaft to a depth of about 140 feet, and has been found to range from 2 to 16 feet in width. The strike is north-northeast and the dip of the ore bed 60° westerly. The ore is fine crystalline and averages about 50 per cent of metallic iron. Northwest of the above described opening, and in the lower ground the Vulcan Iron Company of Boston, opened a vein of ore, which was 12–20 feet wide. The ore was remarkably fine grained. The greatest depth reached was 70 feet. The ore from these mines was used mostly

in the forge at New Russia. About 10,000 tons were obtained from the Gates mine. No work has been done in there since 1882."

The mine was also visited by B. T. Putnam as agent for the Tenth Census in 1880. His record on page 118, volume 15 of the Tenth Census Reports, is also of interest, the more because the observations of those who saw the now abandoned pits in operation, are better than anything attainable today when they are filled with water.

The *Gates* or *Putnam* mine is situated in Elizabethtown township, northwest of Lincoln pond and about 1 mile southeast of the village of New Russia. It is on Gate's farm, but the mine itself has recently been bought by Herbert A. Putnam, and is worked by him for the supply of his forge at New Russia. The existence of a vein of ore here has long been known, and about 12 years ago the Bay State Iron Company opened a mine some 50 rods north of the present workings. Their pit is reported to be between 200 and 300 feet deep (measured on the dip). It is now full of water. Work on the Putnam mine was begun in January 1880. In May 1881, the pit was about 100 feet deep, measured on the foot wall, which dips 57° to the west, and at the bottom 60 feet long. The ore varies in thickness from 18 inches along the sides of the pit to 4 feet in the middle. It will average, perhaps 30 inches. The direction of the outcrop is a few degrees west of north.

A part of the ore is coarsely granular and contains granules of apatite. Before it is used in the forge it is concentrated in the usual manner. Sample no. 1197 represents the ore as it comes from the mine, and sample no. 1198 the separated ore. The samples contained

	No. 1197	No. 1198
Metallic iron	43.21	64.14
Phosphorus	0.456	0.136
Titanic acid	Present	Present
Phosphorus in 100 parts iron	1.055	0.212

It takes about 2 tons of "primative" ore to make 1 ton of separated ore.

The Gates mine was also visited at different times both by the writer and by D. H. Newland when assisting in the field. An open cut about 20 feet wide and dipping 55° southwest was observed. The hanging wall is a dark hornblendic or pyroxenic gneiss, and the foot wall a light colored granitic rock. Very much the same contrasts are thus shown as at Mineville. To the west of this and the Nigger Hill pit much gabbro appears in a series of small hillocks.

Nigger Hill mine. To the south or southwest of the Gates pit is another opening locally called the Nigger Hill, but also described

by J. C. Smock as the Noble mine. Professor Smock records the following in New York State Museum Bulletin 7, page 34, 1889.

Noble mine, Nigger hill, Elizabethtown, Essex co. Another mine of the Champlain Iron Company on lot No. 136 of the North Riverhead tract. The ore has been opened for 150 feet, on a side hill, on the outcrop. The vein is 11 feet wide. The ore bed was first discovered in 1825. No mining has been done in 15 years.

Mr Newland also visited the pit pointed out as the Nigger Hill mine, but whether it is the same one as described above may be uncertain. He observed a pit 60 feet long by 30 to 40 feet wide, opened by stripping off some 6 feet and less of gneiss in order to expose a very flat bed of ore beneath it. The overlying gneiss was a basic hornblendic variety, apparently a member of the syenite series, but the underlying was not recorded. This very flat position of the ore is unusual since the dips of the gneisses are as a rule steeper. It probably chanced to be left by the general erosion at the crest of an anticline or in the trough of a flat syncline. B. T. Putnam did not visit the mine for the Tenth Census, so that no analyses have been recorded.

From some stray notes of Professor Smock there may be other small openings in this hill, but if so, we have not seen them.

Small pits near New Russia. The sudden fall of the Boquet river at New Russia affords a water power which occasioned the erection and operation of a forge during the period of the bloomaries. Ore was naturally sought in the neighborhood and at other points than the Gates and Nigger Hill pits. A series of small beds was discovered along the west side of the valley and small excavations were made at three or four points. To these the writer was guided by Mr Frank Morehouse of New Russia. The most southerly one is the Pitkin bed which was in the foot of the hills just west of the highway about ½ mile south of New Russia. A small pit had been sunk on a thin bed of ore.

Next north is the Castaline a short distance up the valley of Roaring brook and on the south side. Speaking of this and others near, Professor Smock in Bulletin 7, page 34, states, "West of the Boquet river in this town magnetic iron ore in workable extent has been discovered on what is known as the Castaline place, north of New Russia and in the Wakefield, Post and Ross veins. . . Since the stopping of the forges these mines have lain idle. The Castaline is one of the oldest openings in the country. Watson, in his history of Essex county, says that ore was taken out of it about 1800 and used in forges."

Some small pits were located by the writer after search in the woods, but they had long been abandoned and from them few details could be gathered. The rock in the vicinity was a basic, hornblendic variety and was considered a derivative of the gabbros, raising the question of titanium, but no analyses have been made.

The Ross ore bed is in the easterly foot of Oak hill about a mile north of New Russia. There is a lower opening and an upper, perhaps 300 feet vertically higher up. The lower opening, believed to be the Ross bed, exhibits streaks of magnetite in well foliated hornblendic gneiss, while a hundred yards east and 75 feet below, appears acidic gneiss, so that the familiar Mineville section is again shown.

The upper opening is in gneissoid gabbro with massive gabbro near. It is a lean ore 4–5 feet thick striking northwest and dipping at a flat angle to the west. An analysis of a sample by W. F. Hillebrand gave the following [U. S. Geol. Sur. 19th An. Rep't 1899, 3:408]:

TiO_2	5.21
FeO	22.81
Fe_2O_3	30.34
SiO_2	21.42
Al_2O_3	7.03
Cr_2O_3	none
CaO	3.59
MgO	6.92
K_2O	0.41
Na_2O	0.53
H_2O	0.95
P_2O_5	0.14
S	0.04
Cl	0.42
CO_2	trace
C	trace
Mn	trace
Total	99.81
Fe	38.98

This ore is not very high in titanium but it really belongs in the group of the titaniferous magnetites which will be taken up separately. It is curiously high in chlorin, leading one to suspect the presence of scapolite, since the apatite is obviously too small to care for it.

Steele ore bed. Aside from the titaniferous magnetites this is the one remaining occurrence met within the area. It is situated

about a mile southeast of Elizabethtown village and is exceptional in having a thin bed of limestone of the Grenville for its hanging wall. The pit was filled with water so that the lower edge of the ore was not seen. The exposed face was cut by a small fault which is illustrated in figure 30. The ore is a granular magnetite,

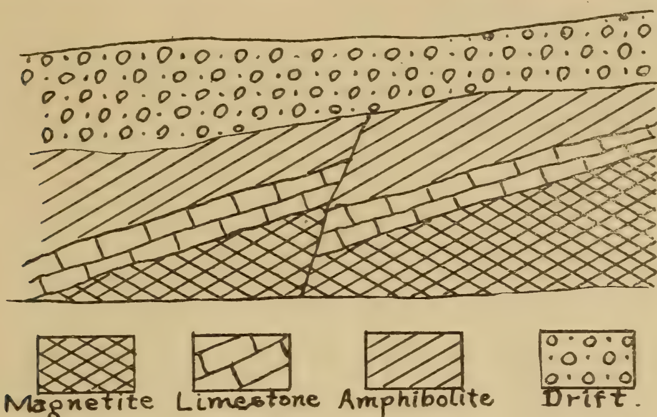


Fig. 30 Cross section of the Steele ore body near Elizabethtown.

and has an apparent strike northeast with a dip west. In only one other instance has ore in or next limestone been noted in the eastern Adirondacks and that is the Weston bed, near Keene Center. Limestones are not far, however, from both the Cheever and the Pilfershire beds, in each case in the hanging.

b The titaniferous magnetites

The interesting mineral deposits of this character are more numerous in the Elizabethtown and Port Henry quadrangles than elsewhere in the Adirondack region, but they are individually not as large nor as rich in iron as are those near Lake Sanford, at the headwaters of the Hudson and in the Santanoni quadrangle. The geological associations are also different. The Lake Sanford bodies are in the anorthosites, whereas, the ones here specially treated are in the basic gabbros. So far as our detailed explorations have gone, the basic gabbros seem to reach their greatest development in the area covered by the two quadrangles here described and extending a short distance north and south. Throughout their many exposures the titaniferous magnetites occur rather frequently and while at present not possessing commercial values as sources of iron, they are of much scientific interest.

The basic gabbros in this section favor the borders or general

contact belts between the anorthosites and the other rocks to the eastward. They form irregular masses of a square mile or less in area, and have revealed few details which would enable the observer to describe them as laccoliths or intruded sheets, or stocks. They certainly do appear in dikes, and the larger masses display characteristic irruptive contacts with the older rocks.

The bodies of magnetite or of intermingled magnetite and ilmenite are merely phases of the gabbro, exceptionally enriched with the iron-bearing minerals. There is no sharp demarcation between so called ore and rock. All the rock has some ilmenite-magnetite. All the ore[1] contains some of the common minerals of the rock, viz: olivine, pyroxene, and garnet, but the feldspar tends to fail. We are compelled therefore to regard the ore bodies simply as basic phases of the gabbro, exceptionally enriched with one of its normal minerals. Details of these relationships will be brought out under descriptions of the individual ore bodies, of which some 10 or more have been discovered. In earlier years much attention was directed to them and in at least four instances they have been opened on a scale which has left pits and tunnels of no small size. In one instance, the Split Rock mine, a magnetic mill was built in the hope of reducing the titanium.

The several deposits will be taken up from north to south so as to begin with the best known and most developed case.

Split Rock mine. From Westport to the northeast the shores of Lake Champlain are formed by a rugged ridge, known as Split Rock mountain, from the rocky islet which is, as it were, split off from its extreme point just beyond the limits of our map. Toward Lake Champlain it is precipitous and rough, forming a general fault scarp with many picturesque reentrant bays where cross faults intersect the master one. The summit of the ridge is very irregular but the northwestern slope is more gentle. On the precipitous eastern front and some 5 miles from Westport a mass of titaniferous ore is exposed at a point about 100 feet above the water. It attracted attention about 40 years ago, and as it stood in a position very convenient for mining and shipping it was opened up on a fairly large scale. Boarding houses were built in a notch in the ridge just above and in the end a mill was erected at the shore of the lake. A road leads out to the westward to the highway as shown on the map.

[1] The word ore is here employed in its purely scientific meaning as implying the richly metalliferous minerals; not in its technical sense as capable of being produced at a profit.

The ore occurs in a moderately large mass of gabbro which can be traced in the vicinity. It is a dark green or black rock, consisting of augite, hypersthene, brown hornblende, garnet, original basic plagioclase, charged with pyroxenic dust and minute spinels, secondary plagioclase in clear rims around the last named, and of the magnetite-ilmenite mixture. The ore is 10 feet or more thick, and forms a flattened body, which strikes into the hill n. 70°-80° e. and dips 50° south. An open cut has been excavated 30–40 feet deep and 25 feet high. From its mouth the old dump of broken ore streams like a talus down to the lake shore. To the south another small opening is reported but this has not been visited by the writer.

While the rock mass is faintly foliated from dynamic effects, there is no sharp transition from ore to rock. The former is simply a basic phase of the latter and the exposures are so good that this locality is a specially favorable one for the study of the relations.

In cracks through the ore a curious isotropic green substance is somewhat rarely found which contains some dusty magnetite and the decomposed remains of feldspar crystals. It has been previously described by the writer as a glass, but its identity can not be sharply determined without a quantitative chemical analysis. Its specific gravity is 2.822 which is higher than the common isotropic minerals which might occur in these relations.

An analysis of the wall rock has been made by W. F. Hillebrand and also one of the ore, nos. 1 and 2 below. No. 3 is an analysis by George W. Maynard, made in the early seventies. Nos. 1 and 2 are from the 19th Annual Report of the United States Geological Survey, volume 3, page 402; no. 3, Journal of the British Iron and Steel Institute, volume 1, 1874.

	1	2	3
SiO_2	47.88	17.90	16.46
TiO_2	1.20	15.66	14.70
Cr_2O_3	tr. ?	.51	....
Al_2O_3	18.90	10.23	.34
Fe_2O_3	1.39	15.85	38.43
FeO	10.45	27.94	23.40
NiO.CoO	.02	not det.	not det.
MnO	.16	tr.	.23
MgO	7.10	6.04	2.13
CaO	8.36	2.86	3.54
SrO	tr.	....	....
BaO	tr.	....	....

K_2O	.81	not det.	....
Na_2O	2.75	not det.	....
Li_2O	tr.	....	....
H_2O —	.18	....	....
H_2O+	.43	1.33	....
P_2O_5	.20	.04	....
V_2O_5	tr.	.55	....
CO_2	.12	.10	....
S	.07	.14	....
Total	100.02	99.15	99.23
Fe	......	32.82	32.59
Sp. Gr.	3.090	4.138	....

When recast the above analyses yield the following percentages which are approximate but unquestionably near the truth. No. 3, however, can not be recast with so great an excess of Fe_2O_3 over FeO.

	1	2
Ilmenite	2.13	29.42
Magnetite	2.09	22.97
Pyrrhotite	.18	.35
Olivine	16.93	....
Pyroxene	13.41	22.91
Plagioclase	56.70	13.62
Orthoclase	4.45	....
Apatite	.34	....
Calcite	.20	.20
Kaolin	3.10	....
Water	.18	1.33
NiO.CoO	.02	....
Spinel	....	5.97
Corundum	....	.92
V_2O_5	....	.55
P_2O_5	....	.04

In the quantitative system, no. 1 comes under class II Dosalane, order 5, Germanare, rang 4, Docalcic, Hessase, subrang 3, Persodic, Hessose; no. 2 falls in class IV Dofemane, order 4, Domitic, Adirondackare, suborder 3, Tilhemic, Champlainiore, rang 1, Permirlic Champlainiase, section 1, Permiric Champlainiose. These last names will suggest the large part that the Adirondack titaniferous magnetites play in the nomenclature of the system.

Ledge Hill mines. About 2 miles a little south of west from the village of Westport an abrupt hill rises to a hight of 1140 feet. On the northeastern side and a short distance below the summit two pits have been opened upon masses of ore in the gabbro. The ore

in one pit has a long dimension in a northeasterly direction and has been exposed in a cut 75–100 feet long and 30–40 feet deep. The second mass has a pit about 25 by 8 feet which is entered by a cut at right angles to its long dimension, and 15 by 15 feet in size. The pits can not be far from the 900 or 1000 foot contour. The wall rock is typical gabbro and while no analyses have been made of the ore, it has all the associations of the titaniferous varieties, is dense and characteristic in the specimens and is believed without doubt to belong to this variety. The name "Ledge hill" may not be the best one but it was given the writer in early work in the region. The locality is in lot 163 of the Iron Ore tract. The notes upon the pits were first published in Bulletin 14 of the New York State Museum, page 350, but the openings were again visited in 1907.

In the southeastern foot of this same hill, approximately on the 700 foot contour, and a short distance from the highway, there is another small pit in a very basic, hornblendic gneiss. Lean, dense magnetite is exposed which is apparently titaniferous. It is a small pit and no analyses have been made.

The remaining occurrences of the titaniferous ores are in Elizabethtown and Moriah.

Tunnel Mountain mines. The Black river heads in Lincoln pond in the southeastern portion of Elizabethtown and thence flows east of north through a wild and narrow pass in which was formerly located the old forge and little village of Kingdom. The relations both of the pond and the river are now somewhat changed from those depicted on the map, because of the damming of the river a few years ago and the erection of an electric power plant for the mines at Mineville. The pond is much expanded and the roads have been somewhat changed. At the point where the river begins to form the boundary between Elizabethtown and Westport, it rounds the foot of an eminence on the northwest, which is called Tunnel mountain, from an adit which was run many years ago near the summit. It was intended that the adit should tap a large body of ore which outcrops higher up.

At the eastern foot of Tunnel mountain, two small pits have been opened which at the time they were visited were on land belonging to John Tryan. The first was 15 feet square by 10 feet deep, and in lean ore which gradually shades into wall rock. It contained much biotite. A thin section revealed titaniferous magnetite, olivine, brown hornblende, deep brown biotite, garnet and clear,

unclouded plagioclase. The biotite is closely involved with the particles of ore. A partial analysis of the so called "ore" by W. F. Hillebrand gave the following:

FeO	21.34	TiO_2	10.55	V_2O_5	.34	S	.10
Fe_2O_3	11.52	Cr_2O_3	.25	P_2O_5	.46	Fe	24.65

The specific gravity was 3.199. The above percentages correspond to

Ilmenite	25.344
Magnetite	1.704
Remaining FeO	6.912

The association with biotite is unusual for the Adirondacks but has been noted in Brazil by O. A. Derby [Am. Jour. Sci. Apr. 1891. p. 311].

Two hundred yards northwest is another pit 15 by 30 feet and 10 feet deep. The walls are gneissoid gabbro and the ore resembles the usual run of the gabbro ores. No analysis has been made, but the specific gravity of 3.964 indicates more iron than the sample from the first pit.

At the extreme summit of the mountain which stands at 1640 feet a mass of ore outcrops, larger than the bodies at the foot, and indicating from its position a character of exceptional resistance to erosion and weathering. An open cut has been excavated 40 feet long, 10 feet wide, and apparently 40 or 50 feet deep. It is now filled with water and its depth is estimated by the size of the neighboring dump. The cut runs north and south and is parallel with the vertical foliation of the walls. Lean ore and gabbro (or strictly speaking norite) outcrop 10 or 15 yards to the west across the strike and gradually pass into the usual massive rock. Some 200 feet vertically below the summit and south of it, in the side of one of the characteristic cross gulches of the mountains an adit has been run with the intention of striking the ore in depth. It must be 100 to 150 feet long, and while it seems not to have cut the ore, it has yielded beautifully fresh samples of the country rock, besides giving the name to the mountain. When examined in thin section, the rock proves to be a true, gneissoid norite, hypersthene being the most prominent bisilicate present.

It is thus analogous to the basic rocks of Norway which contain titaniferous magnetite in that country. Green augite, brown hornblende, plagioclase and garnet are the other components. In the ore, the microscope reveals besides the iron minerals, brown hornblende, serpentinized olivine, garnet and colorless transparent labra-

dorite. An analysis of the ore by W. F. Hillebrand gave the following results:

SiO_2	13.35	P_2O_5	.02
TiO_2	16.45	S	.09
Al_2O_3	8.75	Cl	present
Cr_2O_3	.55	C	tr.
Fe_2O_3	20.35	H_2O	1.68
FeO	28.82	CO_2	.17
MgO	6.63		
CaO	2.15	Total	99.62
V_2O_5	.61	Fe	35.99

When recast this analysis may be split up into the following components which are undoubtedly very near the true proportions:

Ilmenite	30.80	Calcite	.40
Magnetite	29.80	Water	1.68
Chromite	.64	Vanadic oxid	.61
Anorthite	9.45	Sulfur	.09
Spinel	7.38	Phosphorus	.02
Olivine	6.94	Residue, SiO_2	.36
Enstatite	11.40		
		Total	99.57

In the quantitative system this has the same name as the one last recast.

It is probable that from the Tunnel mountain pit came the sample analyzed by Prof. George W. Maynard [British Iron and Steel Inst. Jour. 1874] under the name of the Kingdom Works. He gives

TiO_2	13.15	SiO_2	21.64
FeO	21.24	Al_2O_3	11.86
Fe_2O_3	23.77	CaO	3.54
MnO	.87		
		Total	96.07
		Fe	32.59

Professor Maynard also gives another under the name Iron mountain, Elizabethtown, but the exact locality is not known to the writer.

TiO_2	16.37	Al_2O_3	9.35
FeO	25.44	CaO	7.75
Fe_2O_3	30.36	MgO	.13
MnO	.47		
SiO_2	10.26	Total	100.13
		Fe	40.42

Pits near Little pond. Some 2½ miles south and a little east from Elizabethtown and back from the present highway is a small

lake, known as Little pond. An old road passes it and out through the valley of Kerner brook and is reputed to be the one made by the first settlers in entering what is now Pleasant valley. A little to the northeast of the pond and in two hillocks of gabbro, openings have been made upon bodies of titaniferous ore of considerable size. A great area of dark basic gabbro is present in these hills, and the openings have been excavated in masses of ore occurring in it. The north pit is 20 by 20 feet and 15 feet deep. The south pit, 200–300 yards southeast, is run in a hillside and is 30 by 30 feet. The working face is 25 feet high. The ore contains the same green isotropic substance described from Split Rock. Great expectations were raised by these ore bodies when first discovered; thus W. C. Watson in his History of Essex County, states that the ore forms an entire hill and is inexhaustible in amount.[1]

The wall rock of the pits is the usual green gabbro of this region. The ore is found on microscopic examination to contain, besides the ilmenite and magnetite, brown hornblende, olivine, garnet, and plagioclase. The following partial analyses by W. F. Hildebrand indicate the composition. When recast we obtain the third and fourth columns.

	North pit	South pit
TiO_2	18.82	13.07
FeO	29.78	28.35
Fe_2O_3	26.30	11.16
Cr_2O_3	.75	.37
V_2O_5	.62	.50
P_2O_5	tr.	.32
S.	.06	.10
Total	76.33	53.87
Fe	41.57	29.87
Sp. Gr.	4.41	3.83

	North pit	South pit
Ilmenite	35.27	24.49
Magnetite	38.05	16.24
Chromite	.64	.45
Pyrrhotite	.18	.26

Pit near Lincoln pond. Lincoln pond is the source of the Black river, and was earlier referred to, in speaking of the Tunnel mountain pits. A quarter of a mile west of it in a steep cliff of gabbro, an open cut has been run in on a mass of ore. The opening is locally known as the Kent mine, and it is the largest of all the openings in Elizabethtown. It is 15 feet wide by 75 to 100 feet long, and is continued by a shaft to an unknown depth, as it was full of water when visited. The wall rock is quite massive, and varies in composition from a true norite to a gabbro. Green augite,

[1] N. Y. State Agric. Soc. Trans. 1852. 12:649.

hypersthene, brown hornblende, plagioclase and ilmenite-magnetite are the chief minerals present, while microperthitic orthoclase does not fail. The close relations of the gabbros with the syenites are thus indicated. Garnet varies from absence to richness and at times penetrates the plagioclase in peculiar, fingerlike growths. The wall rock has been analyzed by George Steiger and the ore by W. F. Hillebrand with the following results. In the recasting of the rock the results involve no unusual assumptions, but in the ore all the silicates and the spinel are based on an estimate of the distribution of the bases. The other minerals involve no assumptions.

	Rock	Ore		Rock	Ore
SiO_2	44.77	11.73	Cl	......	.12
TiO_2	5.26	12.31	F	......	tr.
Al_2O_3	12.46	6.46			
Fe_2O_3	4.63	30.68	Total	100.75	99.19
FeO	12.99	27.92	Fe	......	44.19
NiO.CoO	tr.	n.d.	Sp. Gr.	3.09	4.138
MnO	.17	n.d.			
MgO	5.34	3.35	Ilmenite	9.73	22.95
CaO	10.20	3.95	Magnetite	6.73	44.31
BaO	tr.	n.d.	Pyrrhotite	.65	.09
K_2O	.95	.26	Apatite	.67	1.74
Na_2O	2.47	.50	Olivine	2.93	7.33
H_2O	.60	.64	Pyroxene	32.71	5.01
P_2O_5	.28	.82	Plagioclase	37.36	12.53
V_2O_5	n.d.	.04	Orthoclase	5.00	......
CO_2	.37	.32	Kaolin	3.60	......
S	.26	.04	Calcite	.90	......
C	n.d.	.05	Spinel	......	3.55

In the quantitative system the rock comes under class III, Salfemane, order 5, Gallare, rang 4, Auvergnase, subrang 3, Auvergnose. The ore falls in class IV, Dofemane, order 4, Adirondackare, suborder 2, Adirondackore, rang 1, Adirondackase.

The above is unusually high in apatite for ore of this variety. It is also remarkable in yielding a very small amount of free carbon, as to the condition of which in the ore one can only surmise. Graphite would be the most probable mineral.

Oak Hill pit. In speaking of the Ross pit upon an early page, it was remarked that an apparently titaniferous ore had been opened higher up on the hillside. The locality is approximately a mile north of New Russia, on the western side of the highway. A specimen yielded W. F. Hillebrand the following results, which have been recast for the mineralogy. The ore is low in TiO_2 but

it has a remarkably high percentage of chlorine, leading one to suspect the presence of scapolite, as was suggested by Dr Hillebrand. A trace of carbon was found in this sample recalling the results just stated under the Lincoln Pond pit.

The Oak Hill pit is a small one, in gabbro like the others.

Oak Hill ore

TiO_2	5·21	Ilmenite	9·70
FeO	22·81	Magnetite	44·08
Fe_2O_3	30·34	Pyrrhotite	·09
SiO_2	21·42	Olivine	11·44
Al_2O_3	7·03	Pyroxene	10·47
MgO	6·92	Plagioclase	20·04
CaO	3·59	Orthoclase	2·22
K_2O	·41		
Na_2O	·53		
H_2O	·95		
P_2O_5	·14		
S	·04		
Cl	·42		
Total	99.81		
Fe	38·98		

In the quantitative system this ore has the same series of names as the one last mentioned from Lincoln pond.

Titaniferous ores in Moriah. The presence of a titaniferous body near Cook shaft, north of Mineville, but actually in Elizabethtown has been earlier remarked. The possibility of the presence of titanium in the Craig harbor bed has also been suggested. Besides these, however, several occurrences have been mentioned to the writer by Mr S. Lefevre, chief engineer of Witherbee, Sherman & Co. Specimens have been brought in from time to time to Witherbee, Sherman & Co., for analysis, but the writer has not seen the occurrences in the field. Little if any work had been done upon them, so far as known, and while in the field, they were not noted. The bodies are liable to appear in any of the gabbro areas.

West of Mineville is Mt Tom on whose western side is a highway which is prolonged in a trail to Newport pond. An occurrence is reported somewhere near this trail.

Another occurrence has been reported about a half mile due north of Feeder pond, in the southwestern shoulder of the hill reaching 1640 feet.

About 2½ miles west of Moriah Corners (or Moriah on the map), a highway turns due south, and at ¾ of a mile bends sharply

to the east. In the hills somewhere southwest of this angle of the highway another occurrence has been reported.

Commercial value of the above titaniferous ores. So much interest has been felt in the exposures of these ores that a few remarks should be made upon their commercial values. Enough analyses are now in hand to illustrate in a satisfactory manner what may be expected. The percentages in iron, titanic oxid, phosphorus and sulfur may be first summarized, with the name of the sampler.

	Fe	TiO_2	P	S
Split Rock, J. F. Kemp	32.82	15.66	.017	.14
Split Rock, G. W. Maynard	32.59	14.70		
Tryan pit, J. F. Kemp	24.65	10.55	.20	.10
Tunnel mountain, J. F. Kemp	35.99	16.42	.009	.09
Little pond, J. F. Kemp	41.57	18.82	tr.	.06
Little pond, J. F. Kemp	29.87	13.07	.14	.10
Lincoln pond, J. F. Kemp	44.19	12.31	.36	.04
Oak hill, J. F. Kemp	38.98	5.21	.06	.04
Kingdom Works, G. W. Maynard	32.59	13.15	......	......
Iron mountain, J. F. Kemp	40.42	16.37	......	......

It is at once apparent that all these ores are extremely low grade, the richest being 44.19 and only two others reaching 40. Since under present conditions and those which are likely to continue for many years, no magnetite under 50 per cent in iron is of importance as a source of lump ore, unless it should have exceptional purity in phosphorus and sulfur, be lacking in titanium, and be in addition located near a furnace, there is little encouragement to look with favor upon bodies of this type.

The percentages in phosphorus and sulfur are also important features. In sulfur the ores are obviously low. In phosphorus they are variable. In instances such as Split Rock, and Tunnel mountain, they are very low; in others they are quite high as at Lincoln pond. There is a somewhat widely prevalent impression that the titaniferous ores always run low in phosphorus and sulfur but this is clearly unjustified. As with other ores each case must be sampled by itself.

The presence of vanadium in these ores is a matter of much scientific interest and since the element has come into such extended use for high grade steels some have looked to the titaniferous ores as possible sources. If we summarize the results given above, we obtain:

	V_2O_5		V_2O_5
Split Rock	.55	Lincoln pond	.62
Tryan pit	.34	Little pond	.50
Tunnel mountain	.61	Little pond	.04

In just what form the vanadium is combined is unknown. From its chemical properties similar to phosphorus one would suspect some compound analogous to apatite, just as we have pyromorphite and vanadinite, but although the vanadic oxid exceeds in amount the phosphoric the mineral containing it has never been isolated.

Ferro-vanadium is manufactured from vanadium compounds by electrical processes and contains about 25–27 per cent of this element. It would appear as if the percentage of this valuable substance were too low to make it a serious factor in the value of the ore, but as the industry of vanadium is as yet in its infancy one should speak regarding the future in a conservative spirit. In vanadium steel, now so highly prized for its toughness, there is much less than one per cent vanadium. Elementary vanadium constitutes 77.4 per cent of vanadic oxid (V_2O_5).

Magnetic iron ores under 50 per cent and not fulfilling the conditions stated above, must undergo magnetic concentration if they are to be utilized. It is with regard to this method of treatment that the recasting of the analyses into percentages of ilmenite and magnetite has especial significance. The magnetite would be the mineral saved and the one upon which efforts would be especially expended. The iron in the ilmenite we would expect if not hope to lose, so as to reduce the titanium. The iron in the pyroxene and olivine would pass off in the nonmagnetic tailings. So far as iron is concerned we are therefore reduced to considering alone the magnetite and therefore the following tabular summary is presented.

	Ilmenite	Magnetite	Iron in magnetite
Split rock	29.42	22.97	16.63
Split rock	27.95	32.8	23.74
Tryan pit	25.34	16.71	12.10
Tunnel mountain	30.80	29.80	21.58
Little pond	35.27	38.05	27.55
Little pond	24.49	16.24	11.76
Lincoln pond	22.95	44.31	32.08
Oak hill	9.70	44.08	31.91
Kingdom Works	24.64	31.08	22.50
Iron mountain, Elizabethtown	30.80	35.73	25.86

These results show that even if the ilmenite and magnetite are so coarsely intergrown as to make a separation feasible, the grade of the ore is too low to make the separation a likely source of profit. On the other hand the ore is extremely hard and fine grained, quite different from the richer and more coarsely crystalline occurrences at Lake Sanford and parallels can not be justly

drawn. While the concentrates would doubtless be somewhat enriched in iron by ilmenite which would enter them, they would be decreased by some inevitable losses in magnetite, and by just so much as the titanium exceeded a very small value, say one per cent, the operators of iron furnaces under present slag calculations would regard them unfavorably.

The conclusion is quite irresistible that only by smelting in the crude or lump form, and by the development of a process which does not find titanium objectionable, and under conditions where ores of iron content of 35-45 could be utilized, can these deposits be made available. Regarding the smelting of these ores, the following papers by Mr A. J. Rossi should be consulted by any one interested. *Titaniferous Ores in the Blast Furnace* [Am. Inst. Min. Eng. Trans. 1893. 21:832]; *The Smelting of Titaniferous Ores* [The Iron Age. Feb. 6, 20, 1896].

c Red hematite

There is but one locality for this mineral and it is one of no more than scientific importance. On the south side of McKenzie brook, just west of the highway running south along the shore from Port Henry, a series of pits was dug years ago upon a red outcrop which suggested ore. The red color is due to hematite which has developed as a decomposition product along a line of faulting and crushing. The country rock is a basic member of the syenite series and the fault runs about n. 70° w. nearly parallel with the present brook. The decomposition of the pyroxene or hornblende has apparently yielded the red hematite, just as from similar causes certain portions of the richly apatitic ore at Mineville are stained red. The present dumps along McKenzie brook display very lean and greatly slickensided material and there is little reason to regard the occurrence as more than an interesting case of faulting.

2 Limestone

a **Flux and macadam.** Limestones for these two purposes have been chiefly quarried near Port Henry. For flux in the blast furnaces in former years the Grenville limestones were extensively opened. They furnished a coarsely crystalline variety which was a fairly pure calcite except in so far as this mineral was mixed with disseminated silicates. All through the quarry faces streaks of hornblende schist, bunches and lenses of pegmatite, and finely disseminated pyroxenes often altered to serpentine, are present

in such abundance as to cause much waste. From between them the purer streaks of limestone were selected and used as stock in the furnaces. The rejected dumps now furnish interesting material for the mineralogist, since well terminated crystals at times project into pockets of calcite in such relations that they may be easily freed.

The pure, white limestone is occasionally replaced by the serpentinous variety, ophicalcite, locally called Moriah marble, and this will be again referred to under ornamental stone.

The quarries in the Grenville have been shut down for years, since, although the old Cedar Point furnace is still in vigorous campaign the necessary limestone is elsewhere obtained. The largest of the old quarries is the Pease, just north of Mill brook in the outskirts of Port Henry. An impressive face of limestone is exposed with a large black sheet of hornblende schist capping the top. A half mile farther north and on the northern side of the brook which flows into Craig harbor, is another opening, quite similar in geological relations. A third one lies on the western side of the ridge which separates Mineville from the lake, and is just south of the Pilfershire iron mines on the east side of Barton brook. In this last named quarry is the broken dike or sheet of hornblendic rock, shown in plate 9. There are many other places where this same limestone could be opened up if needed but at present there seems to be no call for the material.

The present source of flux for the furnace is the faulted block of Beekmantown limestone on the lake shore just south of Craig harbor. It furnishes a somewhat silicious, magnesian variety and is broken and carted to the furnace yard as needed. Were other varieties required, the Chazy and Trenton ledges on Crown point would deserve investigation, since the Chazy on Willsboro point is a fairly pure calcite, although it varies somewhat in different beds.

In a small way the Grenville limestones have been quarried and burned for lime in former years. The industry was, however, rather a feature of the earlier and more isolated conditions than those of today. The ruins of an old kiln are still recognizable along the road to North Hudson and about 3 miles west of Moriah Corners. Another one is in the western foot of Woods hill, about a mile north of Elizabethtown. From stray bits of clinker it is probable that one also was in existence near the ledge on the northeastern feeders of Jackson brook.

To a small extent the Beekmantown limestone from the furnace quarry, near Port Henry, has been used for macadam, but there

is no doubt that should road metal of this character be needed in the movement for improved highways, this particular stratum should receive careful attention. While it appears near Port Henry chiefly in the two faulted blocks along the lake, it is present in great amount in Westport, and to the south in Crown Point it covers a rather large area. As it appears, moreover, in the regions of the Champlain clay, where the roads are particularly bad in wet weather, it may be worthy of investigation. Being a hard and as a rule silicious variety it would seem to be best adapted of all the local stone for macadam.

As a natural material for use upon the highways the calcareous sand or gravel, which results from the surface decomposition of the Grenville limestone, has been dug to advantage. It is occasionally available in pockets of sufficient size to yield borrow pits of moderate capacity, and it packs under traffic to a very excellent surface.

b **Limestones for building and ornament.** The Paleozoic strata could furnish limestone suitable for structural purposes if desired, but except in the barracks of the old fort on Crown point, they have not been extensively utilized. The Chazy is the best available for these purposes, because of its heavy bedding, and more uniform character. The remains of the old Crown Point quarry can still be seen, but it has not been much if at all utilized in later years. The Beekmantown is also a rather heavily bedded stratum but is irregular in character and harder for tool treatment. The Trenton strata are as a rule too shaly for extended use.

The one ornamental stone within the area here described is the serpentinous marble which appears in several localities in the Grenville series. It has also been used for walls in the village of Port Henry. The more abundant white crystalline limestone is occasionally replaced by beds which are mottled with green serpentine, affording when the mottling is regular and not too coarse, a very beautiful ornamental stone which was formerly placed on the market as verd-antique or Moriah marble. The difficulty in the industry is the irregularity of the serpentine, which at times is in large masses and again in small, shotlike disseminations.

There are three points at which the stone has been taken out. One, the Treadway quarry, is on the brook which flows into Craig harbor, just north of Port Henry and near the point where the fork is shown at its headwaters. A ledge 10 or 15 feet thick was here channeled out in former years but has not been worked for

at least 20 years past. Another quarry is next the highway a quarter mile north of the Cheever mine. A third, the Reed quarry, is in western Moriah just southeast of Broughton ledge and in the curious loop made by the brook which rises at its foot. This last named opening has been more recently worked than the others. The petrography of these rocks has been discussed in the general treatment of the Grenville.

3 Clay

The Champlain clays are very generally present upon the flat Paleozoic strata wherever these appear in the larger areas along the lake shore. The clays constitute the surface over the larger partion of the peninsula of Crown point and are widespread in Westport. Should they be needed in the future as the raw materials of brick they could be furnished in any desirable amount. Up to the present the industry is practically undeveloped and these resources may be considered as reserves. It is probable, that like the similar clays elsewhere they would furnish a good grade of ordinary red brick. The sand for tempering would of necessity be sought in the higher terraces along the Archean front, where the deltas and water-sorted drift contain it. Judicious search would undoubtedly serve to locate the sand and clay in proximity with each other.

Chapter 11
MINERALOGY

The area of the Elizabethtown and Port Henry quadrangles presents some localities of special interest to the student and collector of minerals. It is therefore of interest to embody in a special chapter the notes and experience gained while in the field. The minerals may be classed under three or four heads on the basis of association as follows, but it is not intended to include in the list the ordinary rock-making minerals or others which do not exhibit some feature of special interest. The list amplifies in some respects the one given by the writer in the *Geology of the Magnetites near Port Henry, N. Y.* [Am. Inst. Min. Eng. Trans. 1897. 27:195].

1 Minerals of the Paleozoic limestones, embracing occasional calcite crystals and one occurrence of sulfur, derived from the alteration of pyrite.

2 Minerals of the Grenville limestones, and their associated inclusions of silicates, viz: calcite, diopside, fluorite, garnet, graphite,

hornblende, orthoclase, quartz of the rose variety, phlogopite, plagioclase, rutile, titanite, tourmaline, wernerite, wollastonite.

3 Minerals of the nontitaniferous iron mines. These are of two groups, according as they occur in the ore or in the associated pegmatites or pegmatitic segregations. In the ore proper, there is little beyond magnetite, apatite, calcite, hematite, molybdenite, and siderite, deserving comment and most of these are unusual. The interesting minerals are in the pegmatites and the list is quite large, albite, allanite, amphibole, apatite, arsenopyrite, biotite, fluorite, garnet, lanthanite, magnetite, molybdenite, pyrite, pyroxene, quartz, titanite, wernerite, zircon.

4 Minerals of the titaniferous iron deposits, ilmenite, magnetite.

The above species will now be taken up in alphabetical order with comments on the occurrence.

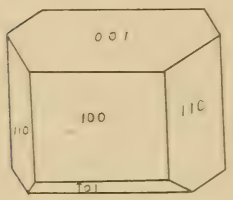
Albite. In 1895 or 1896 the workings in the great pit of Mine "21," encountered a large and coarsely crystalline pegmatite dike. Many carloads of this rock were brought to the surface, of which a comparatively small part is still accessible in the easternmost dump along the main track toward Port Henry. From the pegmatite, cleavage masses of striated and slightly greenish feldspar can sometimes be obtained. Cleavage flakes parallel with the base, give an extinction from parallelism to 3 degrees. On the brachypinacoid the extinction reaches 15 degrees. Prof. William Hallock determined the specific gravity of a piece weighing about 55 grams to be 2.6182 at 14.5° C. This is slightly below the general average (2.62) of albite, but undoubtedly the albite molecule predominated in the piece. Still the general appearance, depending as it does on the greenish hue and the coarse striations, reminds one rather of oligoclase.

Allanite. This mineral, usually esteemed a rare one, is present in unusual amount and has afforded some crystals of exceptional size and perfection. Allanite from this locality was first announced by W. P. Blake in the *American Journal of Science*, September 1858, page 245. The occurrence was in the Sanford bed, or as we now call it, the "Old Bed," the one just north of "21" and at present not much worked. Allanite crystals 8 or 10 inches long, 6 or 8 inches broad, and ½ inch thick are cited. The particular rock mass containing them was apparently long since exhausted, but one may still find small allanites in the pegmatitic streaks of this old pit. James Hall secured one of the large and very perfect ones in the early days and placed it in the hands of E. S. Dana by whom it was described in the *American Journal of Science* for

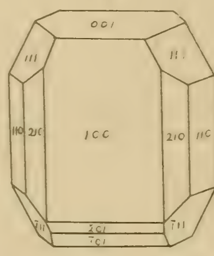
June, 1884, page 479. The specimen was formerly in the Yale collections and it certainly is an unusually fine crystal.

In later years the workings in the Smith mine, through the Cook shaft have brought up much coarse pegmatite in which there are at times great quantities of large allanites, some of which almost equal the dimensions given above. They are not always, or not very often well terminated, and being embedded in quartz and feldspar, and being withal extremely brittle they require great care and patience for their safe extraction. A series of the best secured by the writer were placed in the hands of Heinrich Ries in 1898, and were by him figured and described in the *Transactions of the New York Academy of Sciences*, volume 16, pages 329-30, 1898. The two figures, drawn by Dr Ries are here reproduced.

31



32



Figs. 31, 32 Allanite crystals from Cook shaft of Smith mine, Mineville (after Heinrich Ries)

Amphibole. The most attractive member of this group is a light brown variety which is occasionally well developed in the quarries in the Grenville, north of Port Henry. The crystals up to an inch in length by a half inch in the long diameter have grown from bunches of silicates into a cavity which has afterward been filled with calcite. When the latter is dissolved away, the former remains in almost perfect development. A sharp prism and both the orthopinacoid and clinopinacoid make up the vertical zone, and the terminal faces are a pair of pyramids.

Dark green or black amphibole is common in the coarse pegmatitic aggregates associated with the magnetites on Barton hill. Where it abuts against quartz, it develops the face of the unit prism, but as a rule only cleavage pieces can be obtained.

Apatite appears in great quantity in the rich phosphorus ores of the Old Bed series at Mineville. The grains may reach a quarter of an inch in diameter and are usually of a red color from infiltrated hematite. They impart a red color to the ore itself and thus produce the variety known as red ore. This variety of apatite is separated in the mill and sold for fertilizer.

In the pegmatitic aggregates from the Barton Hill mines, apatite appears in green hexagonal prisms, up to half an inch in diameter. It has also been noted as an inclusion in titanite, having preceded this mineral in time of formation. The angles of the crystals are more or less rounded as so often happens with this mineral.

Arsenopyrite is of rare occurrence in the coarse pegmatite of the "21" mine. It is associated with quartz, orthoclase, albite and zircon. Although as a rule in thin seams long cracks and cleavage planes, one specimen was found, about ½ inch long, by ⅛ inch broad and thick. It had, however, but one crystal face.

Biotite occurs in the coarse pegmatitic aggregates of the iron mines, and in the bunches of silicates in the Grenville limestone quarries. It seldom exhibits crystal boundaries.

Calcite. This mineral is of course present in the Grenville limestone quarries and is occasional in the mines at Mineville. The most interesting occurrence is one discovered in 1888 by Mr W. H. Benedict, then principal of the Port Henry High School. The crystals were measured and figured by the writer in a brief note in the *American Journal of Science* for July 1890, page 62, and the figure is reproduced in the 6th edition of Dana's *System of Mineralogy*. Upon the faces of the unit rhombohedron, with subordinate 4R, are superimposed two scalenohedrons whose combination oscillating with R builds up a low, four-sided pyramidal form. The two scalenohedrons gave $\frac{3}{7}$ R $\frac{9}{5}$ and $\frac{13}{11}$ R $\frac{9}{7}$

At Mineville the calcite appears in crusts consisting of well developed $-\frac{1}{2}$ R. The Miller pit has furnished the best specimens but they are not common.

Diopside, *see* under Pyroxene.

Feldspar. Albite has already been noted above. Oligoclase in great cleavage pieces has been collected from the old Cheever mine dumps and exhibits especially fine striations. Similar cleavage pieces may often be obtained from the pegmatitic masses of the other mines. Labradorite is in endless quantity in the anorthosites. In the mountains along the Schroon valley it can be sometimes obtained in fairly good pieces, but as a rule throughout the area, the anorthosites have been so excessively granulated as to destroy the larger crystals. Orthoclase is common in the pegmatites but is seldom well crystallized. Yet in the area just south in Crown Point huge and well developed orthoclase crystals occur.

Fluorite of massive character and not displaying other than cleavage faces ccurs in great abundance in the Barton Hill ore bed. The new tunnel which has been recently run from the Arch

pit, so as to tap the lenses in depth, has cut large pockets of it, enough to form the entire wall on one side. The fluorite is white and has disseminated magnetite. It is near the lower workings of the Lovers pit. When this pit was in active operation it encountered a peculiar, dense, green rock in small amount which, the microscope showed, consisted of quartz and actinolite. It contained scattered masses of fluorite of pink and green colors and up to 2 inches in diameter.

The most interesting fluorite of all, was however by chance obtained in one of the quarries in the Grenville limestone just north of Port Henry. A rather insignificant crust of dull yellowish color, proved to be this mineral, filled with the wormlike growths, technically called "helminths." The commonest helminths are chlorite in quartz, but of what those in the fluorite consist is not known.

Fig. 33 Helminths of some unknown mineral in fluorite. Actual field about .05 inch

Garnet occurs in the North and South pits on Barton hill in excellent rhombic dodecahedra which are at times distorted so as to be greatly flattened. Aside from this occurrence well crystallized garnets have not been observed, but massive specimens of the mineral are not uncommon in both anorthosites and basic

syenites. In the sedimentary gneisses they also do not fail, and at times are very abundant. They are rich in the hill just east of Moriah Center and north of the Port Henry road and are of a pale pink. The commoner variety in the other rocks is deep red.

Graphite is widespread in the Grenville limestones and in the thin associated quartzites, but does not seem abundant enough to mine in any observed locality. In the quarries north of Port Henry and in the coarsely crystalline calcite it sometimes exhibits sharp hexagonal crystals of diameters a quarter of an inch and less. In the pegmatite streaks it is coarser, but is seldom regular in outline.

Hematite, pseudomorphic after magnetite occurs in the pegmatite of the "21" mine. It is really martite, and retains the shape and cleavage of magnetite, while having a red streak. Some tabular masses of specular ore were met years ago at Fisher hill and were given the writer by E. B. Durham E. M., then engineer for the mining companies.

Hornblende, *see* Amphibole.

Hypersthene, *see* Pyroxene.

Ilmenite appears of massive character mingled with magnetite in the titaniferous ore bodies, but thus far no good crystals have been discovered. These ore bodies are almost barren of good crystals.

Jasper has been afforded by a little vein in the Miller pit, Mineville. The quantity was small.

Lanthanite was found in 1858 by W. P. Blake in association with the large allanites of the Sanford pit, Mineville, now called Old Bed. It formed small crystalline plates and probably resulted from the alteration of the allanite [Am. Jour. Sci. Sept. 1858. p. 245].

Magnetite possesses especial interest not only from the great quantity which is available for mining but because in a large lense of ore developed in the early nineties in the Lovers pit slope of the Barton Hill mines, remarkably perfect crystals of this mineral appeared. The containing ore to the amount of 40,000 tons averaged over 68 per cent iron and carload lots ran 72. The crystals were buried in the granular ore and, as this crumbled readily, they were easily freed. While the greater number were more or less imperfect from the interference of neighboring crystals or granules with their growth, there were found from time to time others up to an inch on the edge of the octahedron which were almost perfect. The faces of practically all the crystals are smooth and brilliant. The common forms were the octahedron with the rhombic dodec-

ahedron modifying the edges. Locally and at the time of production for many miles up and down the Delaware and Hudson Railway the crystals were known as "diamonds." During visits to the mine the writer made a careful study of hundreds and endeavored to detect other faces, freely using the reflecting goniometer in the measurements; but all the determinations led to such extraordinary indexes and to such variable results that the faces were believed to be merely interference planes produced by contact. The plane faces were found to be traversed by regular series of striations most of which follow the octahedral parting planes, but others are parallel to still other faces as described in the reference below to the writer's paper on "Gestreifte Magnetitkrystalle."

The finest of all the crystals of magnetite from Mineville is preserved in the office of Witherbee, Sherman & Co. at the mine and is about an inch in diameter. It is almost a mathematically perfect octahedron, having only one slight interference plane on one apex. Fortunately the matrix is also preserved but the crystal is believed to have come from the Old Bed (or Sanford) pit.

All the pits are from time to time sources of cleavage pieces bounded by octahedral planes and often of large and regular size. The apparent cleavage is, however, really due to a series of parting

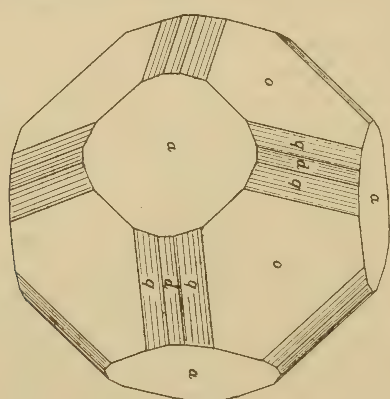


Fig. 34 Magnetite crystal from the Split Rock mine

planes or gliding planes as is usually believed to be the case with minerals of the spinel group. Rarely these plates exhibit brilliant luster.

In the coarse pegmatite of the "21" pit, moderately large but very fragile crystals of magnetite are not uncommon, which are dodecahedral forms built up of octahedral triangular planes, a very common feature of magnetite.

In the dump of the Split Rock titaniferous ore body the writer happened upon a few pieces, which had once formed the sides of a narrow crevice. They were coated with small but brilliant crystals which Mr H. P. Whitlock of the State Museum identified as magnetite of the form shown by the accompanying figure which he kindly drew. The crystals are remarkable for the development of the cube, a rare face in magnetite, and for the trigonal trisoctahedron.

The following papers have dealt with the magnetite crystals from Mineville:

Birkinbine, John. Crystalline Magnetite in the Port Henry, N. Y. Mines. Am. Inst. Min. Eng. Trans. 1890. 18:747.

Kemp, J. F. Gestreifte Magnetitkrystalle aus Mineville, Lake Champlain Gebiet, Staat New York, Zeitschrift für Krystallographie, 19:183. Notes on the Minerals occurring near Port Henry, N. Y. Am. Jour. Sci. July, 1890, p. 62.

Microcline, *see* under Feldspar.

Molybdenite, as is usual in the magnetic mines of the ancient gneisses, occasionally appears in the pegmatitic streaks. In the New Bed pits it has been observed as scales associated with pyrrhotite.

Olivine is a common constituent of the gabbros but seldom if ever in amounts sufficient to see without the microscope.

Phlogopite appears in the quarries in the Grenville limestones and ophicalcites, its characteristic association.

Plagioclase, *see* under Feldspar.

Pyrite is a rarity in the large mines and is only met in some secondary veinlets. It does appear in some of the smaller and leaner ore bodies but not, so far as known, in good crystals.

Pyroxene being the name of a group, the several species under it must be taken up separately. Hypersthene, the orthorhombic member, is common in the anorthosites and gabbros, usually in the microscopic way; but when the former are coarsely crystalline and above all pegmatitic, the hypersthene assumes moderately coarse, platy growths which give cleavage pieces.

Diopside appears in the quarries in the Grenville limestones. Once at the ophicalcite quarry a half mile north of Port Henry, the writer happened on pockets of calcite, into which diopside, brown hornblende and titanite projected in such a way as to be easily freed by weak acid. The diopsides vary from one tenth to half an inch in length and possess shining faces adapted to goniometrical measurement. They are usually white but shade to pink and are translucent. They have been measured and figured

by Dr Henirich Ries in his valuable paper on the "Pyroxenes of New York State," Annals of the New York Academy of Sciences, volume 9, page 171 and figures 9 and 10 on plate 14. They have yielded eight or ten of the faces found on the more complicated pyroxene crystals. Dr Ries analyzed the crystals with the results given under column 1 below. The specific gravity is 3.27.

Much careful study has been given by Dr George P. Merrill to the diopside masses from which the serpentine of the ophicalcites has been derived. An unaltered nucleus was separated by him and analyzed with the results in column 2. The serpentine is given in column 3. The two analyses of the diopside are strikingly alike.

	1	2	3
SiO_2	54.57	55.26	42.17
CaO	23.25	24.48	....
MgO	17.78	19.53	41.33
FeO	1.80	.57	.64
MnO	......	tr	....
K_2O	.70	....	....
Al_2O_3	1.12	.22	.30
Fe_2O_3	....	.22	1.57
Ign	.38	....	....
H_2O	....	....	13.72
Total	99.60	100.28	99.73

Each of these is almost pure diopside (CaMg)O. SiO_2. The serpentine evidently results from the disappearance of the lime and some of the silica, and the assumption of water.

In association with the iron ores and especially in the pegmatitic streaks involved in them crystals of black augite occasionally appear. One of these gathered by the writer at the Cheever mine has been figured by Dr Ries in figure 8, plate 14 of his work just cited. An analysis yielded

SiO_2	FeO	CaO	MgO	Al_2O_3	Fe_2O_3	Total
49.12	15.98	17.30	6.06	7.49	3.53	99.48

Specific gravity 3.60

From the presence of the sesqui-bases this is obviously an augite.

In the ore of the Old Bed group at Mineville a pyroxene of an emerald-green color is frequent, and is similar to the one in the neighboring syenitic rocks. Its color strongly suggests that it is related to aegirite and that it contains the soda-iron molecule in large amount.

Pyrrhotite is rare in the larger mines although seen in some of the smaller sulfurous ones. It is not uncommon in the bunches

of silicates in the Grenville limestone quarries and occasionally yields platy crystals suggestive of its characteristic forms but too rounded for sharp determination.

Quartz. The large mines have yielded a few good quartz crystals of the smoky variety. The pegmatites have corroded and rounded dihexahedrons. The most interesting occurrence is, however, the rose quartz which is obtained in pits just west of the road from Port Henry to Cheever and about a mile and a half from the former. The color is very beautiful and the amount quite unusual. It forms veins in the Grenville series.

Rutile appears in the bunches of silicates in the quarries of Grenville limestone, in somewhat scarce striated prisms and in irregular fragments.

Scapolite, *see* under Wernerite.

Serpentine appears in masses often of very attractive dark green color in the ophicalcite exposures. An analysis is given above under pyroxene.

Siderite appears in small cross veinlets in the Miller pit. It forms a crust under calcite.

Titanite appears both in the hornblendic masses in the Barton Hill ores and in the bunches of silicates in the Grenville limestone quarries, especially the one just north of Port Henry. On Barton hill they are of large size and beauty reaching 2 inches across. The faces are the usual combination of a steep pyramid and the prism.

Wernerite has been yielded by the upper pits on Barton hill, in very excellent square prisms capped by the low pyramid.

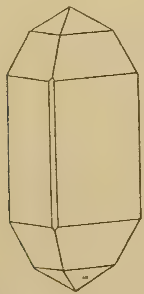


Fig. 35 Zircon crystal from Mine "21"

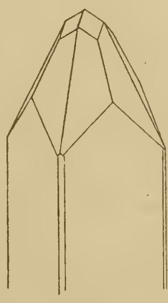


Fig. 36 Zircon crystal from Barton Hill mines

Wollastonite occasionally appears in the Grenville limestones north of Elizabethtown. Its best locality is, however, in the Ausable quadrangle next north.

Zircon occurs in the coarse pegmatite sent up in large quantities from the "21" workings about 13 years ago, and now only available in a few large lumps on one of the dumps. The crystals are of great perfection although of simple forms. 110, 331 and 111 make up the combination. When fresh they are a dark mahogany brown, but some sort of alteration has changed the outer portions of many crystals to an earthy, green and very tender material. The crystals vary in size up to an inch long and three eighths thick. Around them in the matrix are the usual radiating strain cracks. In the hornblendic masses from the dumps on Barton hill, one may rarely obtain small but brilliant zircons consisting of the prisms of the two orders, capped by the zirconoid and the unit pyramid. Figures of each of these are given on page 161 which were kindly drawn by Prof. C. H. Smyth.

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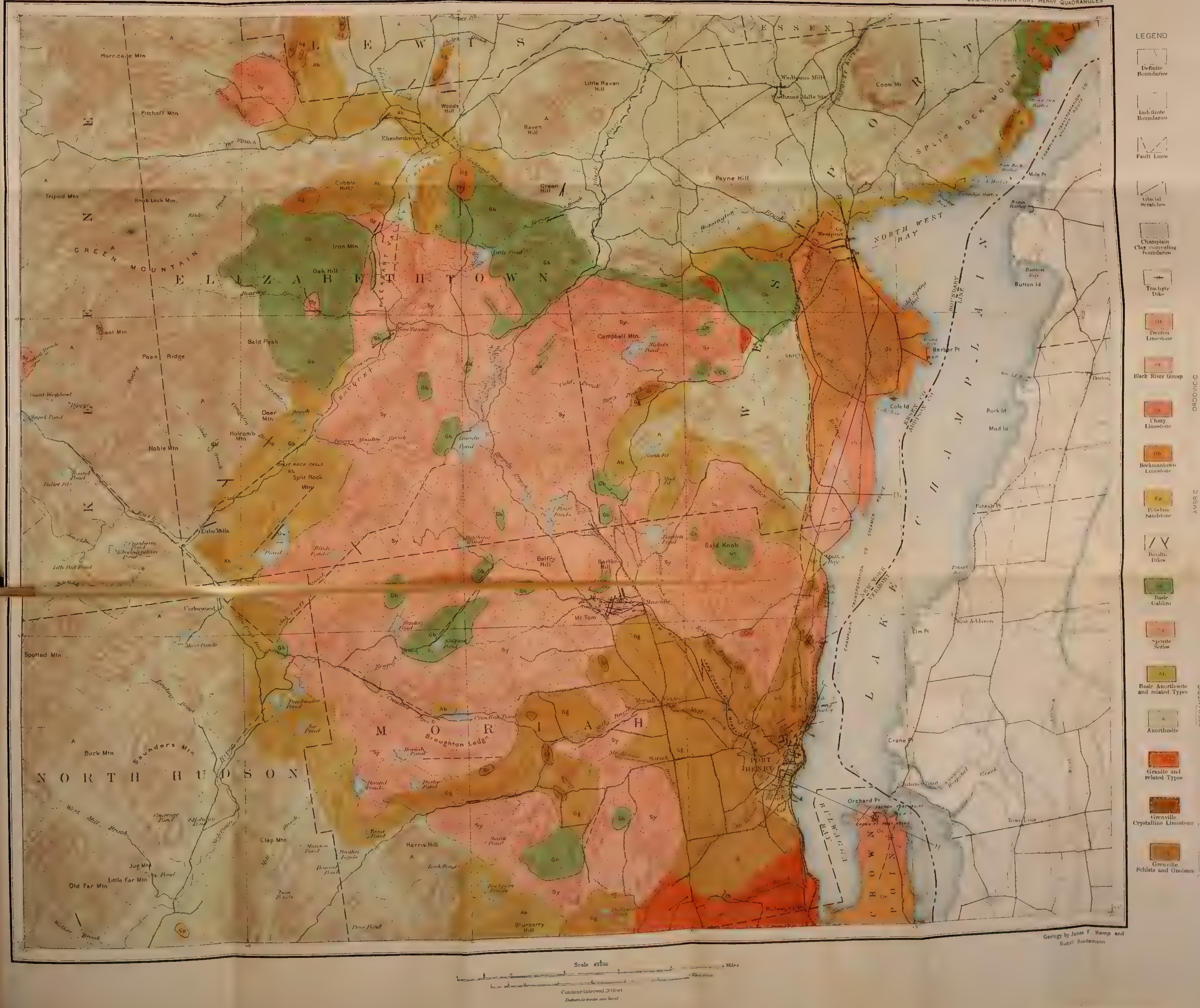

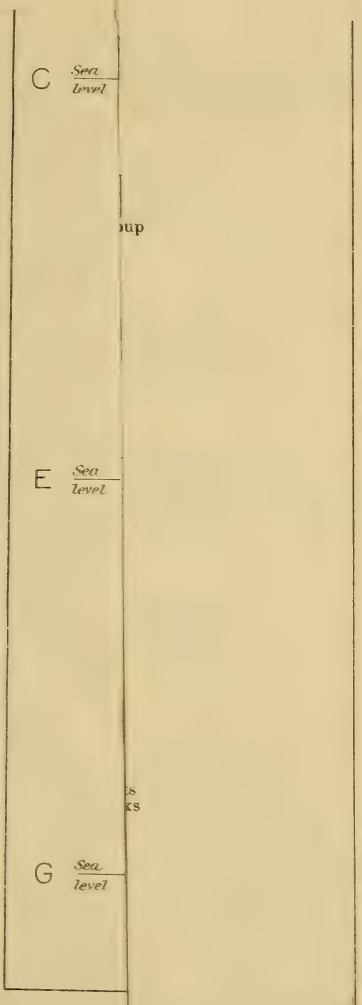
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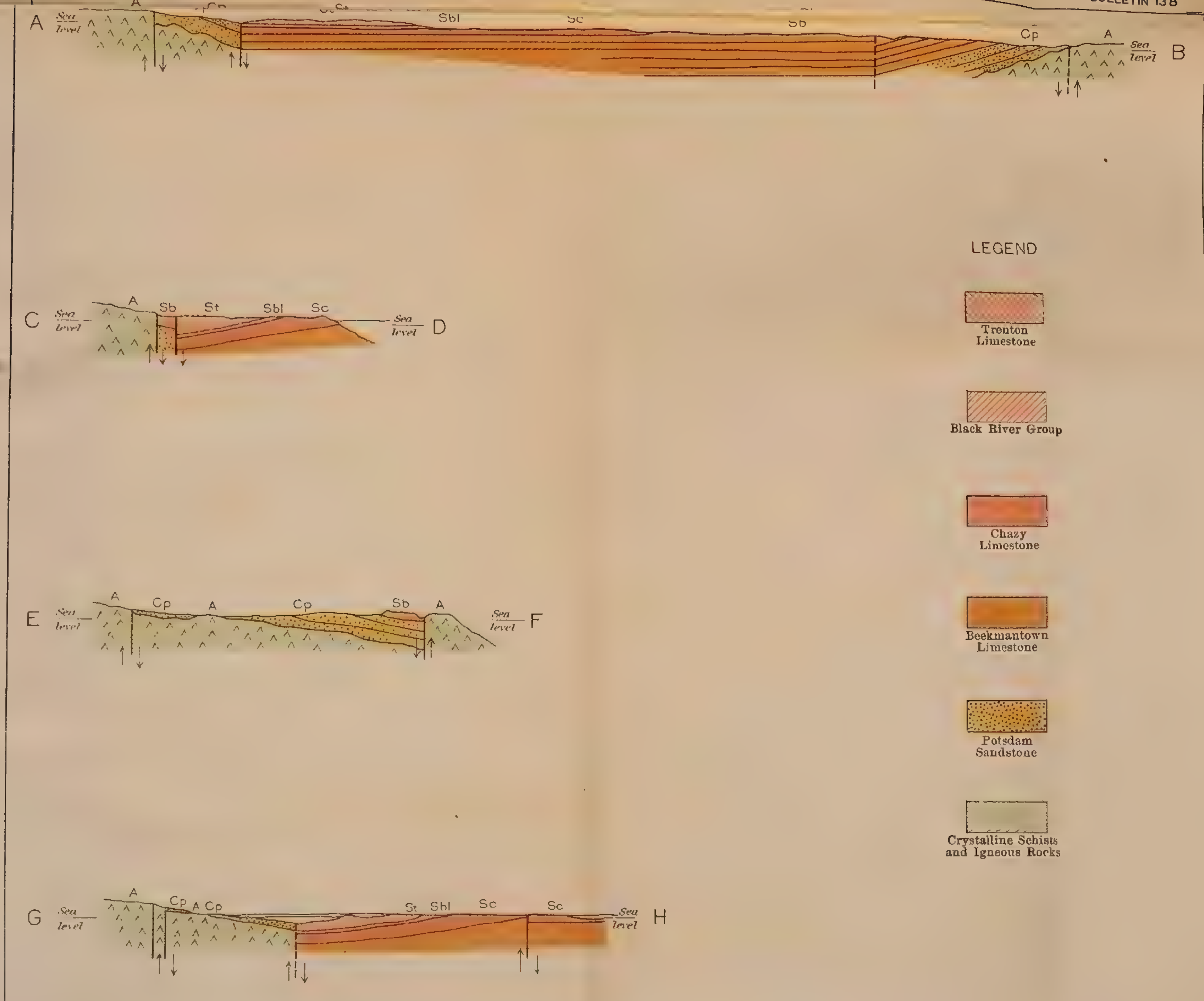

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